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Renovation of vernacular architecture in rural China

Li Ying

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Abstract

With the rapid progress of urbanization in China, a lot of villages face serious brain-drain. A serious problem of culture deterioration arises except in a few traditional villages. Most newly built rural homes are weak and unsafe due to a lack of professional support and building codes. Many large-scale rural reconstruction projects initiated by the government fail because of corruption and irresponsibility. The rural residents suffer from the lack of infrastructure and the quality of their homes.

Presently, there are a few grassroots, activists, architects, architectural critics, media and NGOs working for the renovation of Chinese vernacular architecture and rural settlement. Their works include architectural writing, installation artworks and projects in rural areas.

This paper is an attempt to propose sustainable approaches and alternative patterns to settle grounds for Chinese contemporary rural construction, regarding both architecture, construction systems and user's organization for promotion, by investigating, analyzing and comparing theories and some represented samples of traditional villages, renovation projects and installation artworks from the standpoints of technology, sociology, politics, economy, art, philosophy and sustainability.

Key Words: Vernacular, tradition, renovation, sustainability, technology, art, cooperatives, construction, NGO.

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1 Introduction

1.1 Motivation of the investigation

With the rapid progress of urbanization, a lot of villages face serious brain-drain. The intellectuals of the villages have gone to the cities. A serious problem of culture deterioration arises. The local people have lost faith in their vernacular building culture. They are eager to live in their city-style urban houses. And a lot of valuable traditions of architecture are vanishing.

In order to improve the rural residents' living standard, a lot of exploitative housing projects have been implemented in rural areas by the government. These homes have become a life-long burden involving crushing mortgage payments for rural residents. Due to corruption and irresponsibility in design and construction, most rural reconstruction projects are low-quality.

Except in the large-scale rural reconstruction projects initiated by the government and a few villages maintaining their traditional building culture, most rural residents build houses with help from their neighbors and relatives and the process of the construction is quite long without general planning. Most newly-built homes usually are brick masonry confined with concrete beams and columns. Due to a lack of technical guidance, the housing quality and comfort can't be guaranteed. The orientation of the houses and the layout of the clusters are in disorder so that waste of land is serious.

Except in a few traditional villages, traditional craftsmen are disappearing. At present Chinese government pays more attention to green building with humanistic concern. Indeed, many traditional building techniques using natural materials are sustainable and valuable, but there are only a few guidelines on how to design and build with these materials so that they meet the provisions of modern building codes. Due to a lack of traditional craftsmen and building codes, the newly built traditional buildings are also weak and unsafe.

There are 56% of Chinese people live in rural place, while there is few architect committed to the rural construction because of low profits. The popular discussion about architects is always stay in the perspective of city. Most of the architects become technical elite which vulnerable groups cannot get close to. There is an obvious tendency that architects see themselves as avant-garde artists and lock themselves in the utopia trap of individual innovational formalism. Planners become the technocrats of urban management playing trivial numbers with modeling tools, cut themselves off from the real society, they lost the feeling of living space and decay the target of improving public space. They are technical experts away from the significance of architecture and can't adapt to the changing realities.

With the rapid development of economy and society, the community construction in the areas

has become eye-catching. The rural construction is an issue not only related to the nation and government, it is also worthy of having more attention of the whole society. Particularly after the 2008 Sichuan earthquake, the serious problem of rural construction quality aroused the concern of the international community. Local government and a lot of self-building communities and NGOs have carried out some effective rebuild work in the post-earthquake area, all of them wanted to start a sustainable construction revolution in rural China, but there were still many problems in their practical trials. An available pattern for rural construction is in need.

1.2 Objectives of the investigation

Learning from the theories, installation artworks and projects about vernacular architecture revitalization and traditional villages in rural China. And analyzing them from the aspects of sociology, culture, history, aesthetics, philosophy, climate, geography and construction technology, to discover what's gone wrong in contemporary Chinese rural construction. On the other hand, learning from the advanced construction technologies and architectural designs worldwide to propose suitable approaches to adapt them to the renovation of Chinese vernacular architecture and rural settlements.

To discover everyday building tactics of ordinary people and the strong vital force of vernacular tradition of building in China rather than looking only towards the west for inspiration as many of their contemporaries do, focusing on how to apply them to contemporary architecture. Culturally, to discuss the spirit embedded in the Chinese vernacular building culture, for example, the removable and transferable architecture, social architecture, temporary architecture and low environmental impact. Socially, to discuss the relationship between architects, craftsmen, and rural residents, the traditional mutual-aid construction system, and contemporary construction solidarity, the roles of NGO, foundation, government, activist and architect in rural reconstruction. Artistically, to discover the decorative art and aesthetic aims of Chinese vernacular architecture and their applications in contemporary architecture. Technically, to investigate the promotion of vernacular building technologies and its integration with modern advanced technologies. Socially, to investigate the developing process from traditional mutual-aids construction system to modern cooperatives and construction solidarity in rural China. Economically, to investigate the industrialization and commercial process of natural building materials. Politically, to discover the roles of activist, architect, government, grassroots and NGOs in the rural construction.

Finally, to attempt to propose new sustainable approaches and alternative patterns to settle grounds for Chinese contemporary rural construction, regarding architecture, technology, economy, sustainability, construction systems and user's organization for a promotion.

1.3 Methodology

The study object is not a specific architectural design, but focuses on the practical experience

accumulated in the rural reconstruction projects and the culture embedded in the history and tradition of Chinese vernacular architecture.

Firstly, reading the architectural writing and visiting installation artworks, traditional villages and rural reconstruction projects. Interviewing with architects to learn from their thought and experience. And interviewing the occupants to understand the real state of their livelihood.

Then choosing some representative samples of installation artworks, traditional rural settlements and rural reconstruction projects, and analyzing, comparing and criticizing them from the standpoints of technology, sociology, politics, art, history and sustainability. The empirical research can be positioned by highlighting which theory or project it matches, hence forming a suitable methodology.

Finally, drawing conclusions from the theory and cases studies under new contemporary approaches to the renovation of Chinese vernacular architecture and rural settlements.

1.4 State of the art

In the 1920s the educator Y.C. James Yen, the Architect Liang Shuming and others started the Rural Reconstruction Movement to revive the Chinese Village. There were hundreds of village projects, educational foundations and government zones which aimed to change the Chinese countryside. The earliest and most prominent ones are Yen's Experiment in Ding County, Hebei and Liang's school at Zouping, Shandong.

At the start of the 21st century Wen Tiejun and other activist initialed New Rural Reconstruction Movement to address the crisis they saw in the Chinese countryside.

As of 2009, at its core there are several NGOs and academic institutions, dozens of rural cooperatives and associations, and hundreds of self-conscious participants (including academics, social workers, student volunteers, and grassroots activists). More broadly, the ideas and spirit of NRR have influenced a growing movement of rural experimentation, including many activists who do not use the term "NRR."

The NRR School is critical of the dominant current of utopian marketization, in which the market is seen as a solution to all problems. Instead, NRR supports the creation of rural cooperatives and other forms of cooperative social organization.

Wen hoped China's "people-centered scientific approach" and sustainable development would replace the earlier "vulgar growth" and "blind advocacy of consumerism."

In July 2003, grassroots activist Qiu Jiansheng founded the James Yen Institute for Rural

Reconstruction. This became one of two national centers for NRR activities - mainly training student volunteers and grassroots activists on how to set up, run and support projects such as cooperatives. It had built an environmentally-friendly building without official approval. In 2006 local authorities shut down the James Yen Rural Reconstruction Institute

In recent years, the binary opposition between city and countryside is ever greater. The cities are like magnets, attracting a lot of resource, talents and funds, develop rapidly. While the brain drain of countryside make it become more and more destitute, the tide of peasant workers migrating to cities like migratory birds, most of the young rural scholars from villages work in the cities, they only return home for the holidays. The uneven and uncoordinated development of urban and rural area make the social resource can't be allocated reasonably.

The growing wealth gap and natural disaster stimulate the awakening of the civic consciousness of people with vision, they have a strong aspiration to reconstruct rural place where 56% of Chinese people live. While the development of rural place was ignored in the early stage of Chinese Reforms and Opening. Facing with the fading of villages, many NGOs began to carry out the environmental protection and pay attention to the livelihood of rural China. In the 5.21 Sichuan relief, some NGOs obtained achievement in the reconstruction process, which have a reference value for community construction of rural place. The activist architects and NGOs attempt to explore the construction pattern for rural China, and they are in the early stage of experiment and theoretical research.

The Rural Reconstruction Movement and the New Rural Reconstruction Movement are interrelated with the renovation of Chinese vernacular architecture and rural settlement.

Presently there are activists, architects, architectural critics, media and NGOs working for renovation of Chinese vernacular architecture and rural settlement, such as Zhu Tao, Hao Lin, Hsieh Ying-Chun, Ren Weizhong, Liu Jiakun, ARDA China, Habitat for Humanity China, Wang Shu, Wu Zhi Qiao (Bridge to China) Charitable Foundation, Southern Metropolis Daily, etc. Their works include architectural writings, installation artworks and projects in rural areas.

Zhu Tao, the assistant professor of the Department of Architecture, the University of Hong Kong, is a very active architectural critic in the public sphere. He is concerned by the rural construction in China. He wrote a series of articles after the 2008 Sichuan earthquake, *'Inspiration of Taiwan 9.21 post-earthquake reconstruction'*, *'New School Project Proposal'*, *'Guard Hu Huishan Memorial'*, *'Beautiful Houses of Shigeru Ban'*, etc. and a series of articles discussed on community participation in architecture, such as the interview cooperated with the Southern Metropolis Daily, *'One Support Another – Architecture, Media and Civil Society Construction'* (2008), *'From Mobilize the Masses to Citizens participation and From Quarter development to Community Construction'* (2009), etc.

Southern Metropolis Daily (SMD) is a Chinese prominent mass media, which commits to promoting Chinese built environment. In 2007 it held the Chinese Architectural Thoughts Forum which provides a pure platform for Chinese building culture communication. In 2008 SMD organized the China Architecture Media Awards, in an attempt to 'promote architecture's engagement in China's construction of the civil society'. The 'Civil Architecture' according to Awards Charter refers to the architecture works concern people's livelihood, housing, community participation in architecture, built environment, public space, vernacular building culture, humanity, etc..

HAO Lin is Managing Director of INTEGER Intelligent & Green, Director at Oval Partnership, Co-founder of Rural Community Development Group. The project led by him KPMG -CCTF community center in Sichuan is a long-span public building. The material is reconstituted bamboo. In the project, he cooperated with the local traditional carpenters and organized a construction community made up of villagers. In order to establish a sustainable development model in the village, the project also includes bamboo construction skill training for villagers, improvement of local infrastructure and local bamboo industry. The community center became a demonstrating project. After the project, villagers continually built with their product - reconstituted bamboo in the pattern of community participation and sold it throughout the country. The project kick-started a green revolution in the village.

Activist-architect Hsieh Ying-Chun lives his ideals by creating eco-structures and empowering earthquake victims in Taiwan and mainland China to rebuild homes. In 2005, Hsieh had participated in community education at the James Yen Rural Reconstruction Institute in Hebei province at the invitation of Wen Tiejun, so the architect was familiar with conditions in mainland China. Hsieh organized the reconstruction of housing and communities in disaster-struck areas while faced with two challenges: to build houses within an extremely tight budget (25%-50% of the market price) and to base the projects on the notion of sustainable construction, green building, cultural preservation and creation of local employment opportunities.

Ren Weizhong is one of the activists working to transform his hometown Anji County into an eco-town. He was trying to establish an eco-friendly community model that can be followed as a standard. He actively promoted environmental awareness among his townsmen, and paid out of his own pocket to build eco-homes as demonstration projects. His green initiatives were also recognized by the local government and massive projects were launched in Anji.

Liu Jiakun's installation artwork - 'Rebirth Brick' is for promoting a material manufacturing project for reconstruction in 2008 Sichuan earthquake-stricken zones. Material debris left as a result of an earthquake is collected, sterilized and recycled to be used as an aggregate. The wheat branches mixed in with the debris and concrete, to create light-weight bricks to be produced on a small scale efficiently using a semi-manual leveraging tool which is widely used in China by the local

crafting industry. The machine is easy to use and suitable for the poor condition of the aftermath site, it is applied to reconstruction practice because of its economy and quality.

Wang Shu's installation artworks 'Decay of a Dome' and 'Squarely Sphering' and the long roof of Wa shan Guesthouse are renovations in practice of traditional reciprocal frame.

Wu Zhi Qiao (Bridge to China) Charitable Foundation is a charity registered in Hong Kong. Through encouraging volunteers, especially university student volunteers from Hong Kong and Mainland China, to design and build footbridges and village facilities in remote and poor villages in the Mainland with green concepts. The foundation developed bridge prototypes and construction manuals for typical river settings in the village. Apart from building bridges, the Foundation implemented comprehensive village rebuild demonstration projects with the support of the Ministry of Housing and Urban-Rural Development of the People's Republic of China. Hopefully, these projects will serve as useful references for village redevelopment and will be adopted by local governments as models for building sustainable and ecological architecture.

ADRA CHINA is a non-governmental organization providing sustainable community development and disaster relief. They have been working in China since 1998. Their key program is the introduction and extension of safe, healthy, sustainable, and energy-efficient straw bale construction practices. ADRA has provided technical and financial support in the construction of more than 600 straw bale homes and three schools in rural villages, and trained hundreds on straw bale housing construction, including local government officials, construction workers, architects and homeowners. Since its beginning, more than 2,000 people have benefitted in Heilongjiang Province. In response to a rising need for housing following the 8.0-magnitude earthquake that struck Sichuan in 2008, ADRA China traveled to Sichuan to develop new designs suitable for the more humid conditions of the Sichuan Basin. In 2009, ADRA launched a new project to introduce straw bale housing construction technology to assist families living in China's earthquake-affected Sichuan Province.

2 Characters of vernacular architecture

Interest in vernacular architecture started as a reaction to the non-human outcome of modern architecture practices which lasted for 60 years. Architectural practices of the 1950s and 1960s, the expressions and techniques of vernacular architecture were studied by architects and planners. There was a movement “learn from vernacular architecture”, to research the pre-industrial city and rural place as main influences for new methods of design and planning. Vernacular practices in dwellings and buildings were described as essentially human and evolutionary, as a way to become modern. Bernard Rudofsky (1984) in ‘Architecture without architects’ preface, ‘Architectural history, as written and taught in the Western world, has never been concerned with more than a few select cultures. In terms of space it comprises but a small pan of the globe-Europe, stretches of Egypt and Anatolia-or little more than was known in the second century A.D.’ Out of our view of architectural history, a lot of architecture that ‘we shall call it vernacular, anonymous, spontaneous, indigenous, rural, as the case may be’ is generating, developing and disappearing in its unique evolutionary mechanism. These buildings host various people’s life, their unique form is the certain landscape of an area. The celebrated book of Amos Rapoport “House form and culture” was very influential in focusing attention on the vernacular architecture and its multidimensional meaning including climatic, resources, and socio- cultural factor. The significant work of Paul Olive addresses aspects of vernacular architecture in many parts of the world as a social and cultural phenomenon. The work of Hassan Fathy addressed many aspects of the concept sustainable architecture while developing new villages for Egyptian peasants using available resources, employing self-help methods, applying vernacular construction techniques, while recognizing social and cultural aspects of architecture. The study of vernacular architecture is a broad subject and is increasingly attracting the interest of many specialists from a variety of fields.

Since the beginning of time, humans have been in the need of a shelter in order to be protected from the natural elements. This primitive need has intuitively urged people to start building their own dwellings which according to the context in which they were living, had a series of characteristics that made them differ from the dwellings of people who lived in other areas. This set of building traditions has been described over time in a variety of ways by people who sought the study of this field of architecture and the main terms being used to do so were: indigenous, folk, anonymous, primitive, and popular architecture. However, the term which most comprehensively describes these dwellings and their traditions is ‘vernacular’. Derived from the Latin *vernaculus* (native), these pieces of architecture are categorized based on the fact that they follow certain building traditions (religious, tribal or localized). These building traditions place vernacular dwellings within their environmental, national as well as their cultural context. In addition, their building form is strongly defined by the local material resources and technologies available at the time, the structural systems employed, as well as the environmental conditions of the context. On the cultural aspects the beliefs, the behavioral patterns and the community’s

social structure have a bearing on the building type, functions and meanings of these dwellings. Others also believe that the analysis and study of the economic activity of a culture also have an important role to play in defining vernacular architecture. (Bourgeois and Jean-Louis, 1983) Lawrence (1983) notes that it's not just architects, but also ethnologists, historians, geographers, social anthropologists, sociologists and psychologists. Vernacular architecture is heavily influenced by culture's traditions, customs and beliefs, so naturally the study of it can reveal a great variety of information useful for people from many areas of study in a great variety of ways. Each of those fields takes its own positions in vernacular architecture study in order to obtain the information relevant to them. Therefore, in the study of vernacular architecture a series of different approaches and concepts have been developed, such as sustainability, technology, aesthetic and formalist, function, political, historical, etc.

2.1 Vernacular architecture belongs to art

The 'Architecture' essay of Adolf Loos (1910) is commonly cited as further evidence that Loos opposed the idea of architecture as art, but Loos actually clearly locates the discipline within the arts and recognizes that 'only a very small part of architecture belongs to art'. Vernacular buildings are portrayed as at peace with their surroundings, and architecture as a disruptive force that elicits emotional responses — whether it is the product of a 'good' or 'bad' architect, in Loos's terms. Loos proposes that vernacular building lacks self-consciousness as simply a crafted product of culture. The appearance of buildings was simply a consequence of the time of their production, and they were not consciously designed at all. Loos's designs for country houses also illuminate the central hypothesis because, unlike his urban houses, the exterior forms generally reference vernacular building form, and so operate as functional furnishings in their entirety, rather than attempting to operate as sculpture. In Loos's writing he also conceived of the balance between building and architecture differently in these projects—a product of craft inflected by moments of art, rather than an art object furnished by the products of craft.

2.1.1 Modern day aesthetic usage of vernacular architecture: Iconic architecture and Critical Regionalism

Buildings have 'commonly been classified according to explicit aesthetic or functional qualities: above all, according to their use, their nomenclature, and/or their 'historical' style based on the doctrine of established architectural canons' since the eighteenth century (Lawrence, 1983). The vernacular fashion of the time would have a certain easily recognizable set rule or doctrine, enabling them to be applied at any time. Rudolfsky (1984) best exemplifies this approach in his book *Architecture without Architects*. Nevertheless, this approach and his book received criticism. Oliver (1969) felt Rudolfsky and the aesthetic formalist approach disregarded methods for understanding why or how vernacular buildings were constructed in the first place, which was

a disservice to Brunskill's (1987) definition of the vernacular that 'the function of the building would be the dominant factor' (Brunskill, 1987:27).

Nowadays, the original and intended function of the vernacular has witnessed a monumental reconfiguration and adaptation due to the impact of internationalism, as the empirical research will later explore. The vernacular, once a resistance against global trends and styles, has now been conquered and mobilized by foreign forces. International architects now look to incorporate vernacular elements and components, such as traditional motifs and ornaments, within their modern day designs in an attempt to display a continuation of the past.

The impact of internationalism and globalism has forever affected architectural production and practice in countless ways. Not only do we interact and live differently within our own urban environment, but the manner in which we design, communicate and travel has had an astounding impact on the whole profession and output of architecture. The evolutionary process of architectural production in an increasingly globalized world has meant that overseas work has become a routine aspect of contemporary practice. This means the understanding of locality and context in an unfamiliar land is a vital part of the job (McNeill, 2009). McNeill (2009) offers a thoroughly researched and well-referenced publication, *The Global Architect: Firms, Fame and Urban Form*, which provides a fascinating insight into the effects of globalization on both vernacular architecture and the built environment. Notably due to the digital media age and today's ease of transportation, McNeill (2009) notes that 'the territorial boundaries that had kept most architects tied to a small set of national markets no longer make much sense for design firms capable of operating in the dynamic economies of the Gulf and China' (McNeill, 2009:1).

One manner internationalism has affected the configuration of the vernacular is, as McNeill (2009) mentions, the use of local ornamentation and traditional design, which is a tried and tested method to integrate a contemporary piece of architecture to relate to its context, culture and indigenous population. McNeill (2009) uses the Petronas Towers in Kuala Lumpur as an example. It was designed by Argentine-American architect César Pelli who used 'Islamic motifs incorporated into the façade and floor plans (which is) an attempt to fuse standardized western production methods with locally sensitive design vocabulary' (McNeill, 2009:117). Bunnell (1999) goes further by discussing why the use of vernacular motifs and decoration was used, and countering those critics who see them as simplistic gestures, by suggesting that they are actually intentional to be easily quotable and recognizable as *iconic* and aim to feature in adverts, postcards and in Hollywood films. The *iconic* is an interesting concept that merits further attention in the exploration of the changing role of the vernacular. The endorsement of *iconic* architecture is becoming an increasingly popular trait as a product of globalization, by creating instantly recognizable forms that can be transmitted and branded globally (Jencks, 2005). Iconic architecture is defined as buildings and spaces that are seen as famous by those in the field as well as the public at large, and also have special symbolic and aesthetic significance (Sklair, 2006). In a lot of cases, it has been influenced from the vernacular that have been in operation, in order

to create the 'special symbolic and aesthetic significance,' and produce a sensitive and fluent dialogue with existing contextual buildings. This allows for the generated iconic form to be showcased on a worldwide scale, whilst still retaining an element of pride in their origin and location, as the Petronas Towers demonstrate. Jencks (2005) writes in his book *Iconic Building*, which is that, due to the effect of globalization, there has been a shift in the typology of what can be classified as 'iconic architecture' in today's terms. Jencks (2005) argues that it used to be the cathedrals and palaces that were the most familiar symbols of the city, but now it is museums or shopping malls or other similar modern inventions. Therefore, the vernacular components' function has changed in this respect. So, even if it was once used as a direct application to a cultural or religious requirement within a cathedral, the same element may then be used for a completely different purpose in a twentieth-century shopping mall, for instance. However, iconic architecture is a superficial portrayal of the vernacular. The vernacular has been mobilized and conquered by the international architecture to form an iconic landmark to produce an exhibition of international architecture. Sklair's (2010) discussion of transnational social spaces also shows the role of internationalism in evolving the vernacular. Transnational spaces 'are spaces, like globally branded shopping malls, theme parks, waterfront developments and transportation centers, that could literally be almost anywhere in the world' (Sklair, 2010:139). The reaction to the one-size-fits-all approach has led many to reconsider the application of the vernacular and regional factors (McNeil, 2009). The international architecture also can bear the responsibility for helping to preserve cultural identities. In order to call for regionalism to collaborate with internationalism as the way forward, there are debates on Critical Regionalism.

Critical Regionalism facilitates further analysis of the literature on the tensions of local and global drivers. The debates regarding Critical Regionalist rhetoric were generated out of the reaction against and refusal to accept the mass uniformity of the modernist era. Since regionalism is often seen as rigid localism as opposed to more open and common cosmopolitanism, Critical Regionalism was an attempt to negotiate between the two poles to avoid the excesses or limitations of each. It was to permit connections in time and space between individual, local moments of cultural struggle and the wider patterns of history, culture and politics that it related to (Reichert-Powell, 2007). In order to continue a progressive and modern urban development, theorists did not seek a complete return to traditionalist vernacular architecture, but wanted to integrate regionalist and geographical elements into the modernist and post-modernist movements. It was a theoretical model that wanted to engage its particular geographical and cultural circumstances in deliberate, subtle and sometimes vague design strategies within the latest trends and fashions, in a union of architectural elements taken from the past and present and from local and global arenas. In making this engagement, Critical Regionalist architecture was said to be an attempt to counter placeless homogeneity and much mainstream international modernism.

Most agree that Frampton is the best-known author on Critical Regionalism. Frampton (1983) wrote that Critical Regionalism was a form of 'resistance,' a deliberate reaction to the general,

universal standards, practices and norms. It was to be a new wave of architectural thinking that celebrated the place of origin and in which it was grounded to 'cultivate a contemporary place-orientated culture' (Frampton, 1983:35), yet nevertheless still modern, appropriate and fashionable. Frampton (1983) points out those Critical Regional architects that he had cited, such as Tadao Ando, Oscar Neimeyer and Luis Barragan, did not have a defined style or common design characteristic between them with their buildings. The buildings of Critical Regionalists did not exhibit 'a received set of aesthetic preferences' (Frampton, 1983:35). Instead, Frampton (1983) showed how Critical Regionalism was a process that was applicable to a range of situations and localities that tended to be independent depending upon their location. It is during this architectural process that an architect would have to demonstrate an appreciation of geographical features and be influenced by past vernacular designs for strategies and solutions, and still converse with modern world architecture. Critical Regionalism was at once inherently dialectical and contradictory. As Eggener (2002) notes, Critical Regionalism depended upon universal modernism, even though it worked against it. Set against the backdrop of this coalition of local physical and cultural characteristics with more modern universal practices and technologies, to be a true Critical Regionalist was an extremely delicate balancing act. Eggener (2002) argues Critical Regionalism is such a formation, as it identifies an architecture that purportedly reflects and serves its locality, yet is itself still a construct most often imposed from the outside and from positions of authority. Eggener (2002) has suggested Critical Regionalism is a complex paradox within itself, having undermined its own constructive message and confounded the architecture it promotes. Even though it represents and cherishes the local identity, it cannot be established or practiced without the influx of foreign power and manipulation. In *Towards a Critical Regionalism: Six points for an architecture of resistance*, Frampton recalls Paul Ricoeur's "how to become modern and to return to sources; how to revive an old, dormant civilization and take part in universal civilization". According to Frampton's (1983) proposal, critical regionalism should adopt modern architecture, critically, for its universal progressive qualities but at the same time value should be placed on the geographical context of the building. The emphasis, Frampton says, should be on topography, climate, light; on tectonic form rather than on scenography (i.e. painting theatrical scenery) and should be on the sense of touch rather than visual sense.

There are subtle differences between the regional and the vernacular. Mumford (1941) demonstrates 'Regionalism is not a matter of using the most available local material, or of copying some simple form of construction that our ancestors used, for want of anything better, a century or two ago. Regional forms are those which most closely meet the actual conditions of life and which most fully succeed in making a people feel at home in their environment: they do not merely utilize the soil but they reflect the current conditions of culture in the region' (Mumford, 1941:30). Mumford (1941) went further to stress that it wasn't nostalgia for the past vernacular that he envisioned. 'The forms that people used in other civilizations or in other periods of our own country's history were intimately part of the whole structure of their life. There is no method of mechanically reproducing these forms or bringing them back to life; it is a

piece of rank materialism to attempt to duplicate some earlier form' (Mumford, 1941:30). According to Critical Regionalists like Mumford (1941), modern architecture must progress through a greater appreciation of regional factors. However, what cannot be dismissed is that the vernacular form was a direct response to the geography of the region, and this is where the connection lies between regionalism and the evolution of the vernacular. Some examples of vernacular architecture can be considered primitive, but they were simple and efficient solutions, derived from direct experiences with nature, oriented towards avoiding waste and protecting the environments. The vernacular could not be constructed without the consultation of regionalism and environmental factors, and therefore the two notions are intrinsically intertwined.

2.2 Sustainability

Traditional architecture has developed over many centuries through a process of trial and error. The collected wisdom of each place's native inhabitants has made them capable of finding viable solutions on working with the climate extremes. However, over the last few centuries phenomena such as the technological advancement and the globalization have created a trend towards an international style of buildings mainly influenced by the Western world which has resulted in vernacular building traditions to become obsolete. People rightfully seek for high levels of comfort within the environment of their house. This can be achieved by incorporating high-tech ventilation systems as well as many other products of technology in buildings. However, these systems are expensive in initial cost and very energy consuming. In order for this energy to be consumed many of the earth's natural resources have been for centuries irrationally exploited and caused harm to the environment in many ways. This problem has brought the world to a point where these issues need to be addressed responsibly in order for the world as we know it to stay in existence. As a result, a tendency towards more climate responsive buildings has started to become the new trend in the field of architecture.

With the term "sustainability" rapidly becoming more and more popular in the architectural community and it is now the most ethical way to practice architecture in the twenty-first century. A sustainable society is one that can persist over generations, one that is farsighted enough, flexible enough and wise enough not to undermine either its physical or its social system of support. Sustainable architecture is related to a worldwide movement towards sustainability in all aspects of life. It is the act of building that supports the existence of humanity without destroying its environmental and cultural context. Some authors consider sustainability movement as "another step in the process wherein society has moved from a nomadic hunting order, to an industrial order and currently moving to an information based order." In general, it is an attitude and way of thinking and acting responsibly towards the context of our existence. It is a term that represents the social and cultural shift in the world order, patterns and styles of living, a new attitude and way of looking at the world. The history of thinking about sustainable development is closely linked to the history of environmental concern and peoples' attitudes to

nature. Both represent responses to changing scientific understanding, changing knowledge about the world and ideas about society. The basic definition of the term sustainability is derived from the dictionary word Sustain meaning: 1. The bear weight of, hold up, keep from falling or sinking (c.f. Support), 2. Enable to last out, keep from falling, give strength to, encourage, 3. Endure without giving way, stand, and bear up against, 4. Undergo, experience, suffer, 5. Allow validity of, give a decision in favor of, up hold, 6. Bear out, tend to substantiate or corroborate, confirm, 7. Keep up or represent adequately, 8. Keep going continuously. Sustainable is an adjective describing an object to which is given support, relief, nourishment, or supplied with sustenance and thus continuously kept alive or prolonged. (Adam and Jeanrenaud, 2008)

The popular interpretation of words “sustainable architecture” describes an approach to architectural design that minimizes sustenance or resource consumption so as to prolong the availability of the natural resource. However, the definition of “sustainable” does not imply a minimization of sustenance. “Sustainable” simply expresses the fact that resource does maintain our environment. Sustainable architecture describes the fact that we receive what we need from the universe. This realization compels us to respond with care or stewardship in the use of those resources. Sustainable architecture, then, is a response to an awareness and not a prescriptive formula for survival. Sustainable architecture is part of a larger concern of creating a sustainable environment, which is an environment for human occupation, performance and the support of life to which sustenance or nourishment is continuously given.

However, most of the principles of sustainable design where already applied in traditional dwellings many centuries ago proving that it is possible to provide comfortable environments within a house using traditional solutions. In vernacular architecture, sustainability is manifested in the design of buildings, use of materials, environmental and social consciousness. There are indeed many lessons to be learned from vernacular architecture. On the other hand, aspects of sustainability are absent from almost all modern buildings for many reasons: rapid development, use of unsustainable material, design methods, and construction systems all contribute to the absence of sustainability in modern buildings. Yet, an important aspect contributing to this situation is the absence of building codes and regulations enforcing sustainability in the design and construction of buildings. This is not to say that designers should blindly mimic the vernacular traditions of the place in which they practice. Instead, computer technology, modern construction methods and innovative materials can be used in collaboration with vernacular traditions in order to search for ways of providing climate responsive houses. Ignoring a place’s architectural heritage and disregarding the wisdom of the past is at best ill-informed if not arrogant. (Despina, 2010)

2.3 Technological advancement

A more powerful and dominant constituent can directly impact the development and

configuration of a lesser one. As with many cultures around the world, most of the contemporary architecture in Eastern Asia have lost their identity and they are now mere followers of global trends mainly influenced by Western cultures. All the above were results of globalization which was a consequence of the technological advancement. The technological advancement of modernism has been in utilizing and adapting the vernacular. The rapid technological advancement that the industrial revolution brought along had a massive impact on this as well as the way people lived until then. It has certainly expanded many possibilities in a great variety of aspects of life. However, there is a belief by many that 'technology' and 'vernacular' are two contradictory terms and cannot coexist in an architectural proposition. This statement might be right to an extent but this is only because people have been using technology in the wrong way when it comes to architecture design and construction. Technology with respects to architecture, has enabled a more active control of the environmental conditions of buildings through the aids of mechanical systems to regulate the internal comfort levels, it has given many opportunities on the choice of materials other than the locally available ones, it has pushed the limits of building materials' into new levels and has given many other possibilities which whether they were beneficial or not is a controversial matter. However, this series of new capabilities has given the power to many people responsible for the design of these buildings (the majority of them being architects) to design without considering the context in which they build. As a consequence, this created numerous problems. The most significant ones are the harm to the environment and the loss of cultural identity in the architecture of many around the world.

decades of irrational exploitation of the earth's natural resources due to the new abilities that technology brought along, and after many examples of inappropriate-for –their-contexts designs issues of sourcing and transporting materials, the impact of a building on its environment during and after construction (i.e. the carbon footprint of the building) have emerged as a topic of concern in the architectural community. Moreover, the technological advancement has brought some other issues as well. As previously mentioned, every culture in every corner of the world has its own building traditions. This set of building traditions were followed by everyone in the given community and they were in a way an unwritten building law which everyone accepted and obeyed without questioning. They were considered to be the principles of building in each area and they were a matter of concern for everybody living in the given area and were handed down from generation to generation. However, with technological advancement came the globalization which in turn might have had a catastrophic effect on the ways people build. It has brought a homogenizing effect in buildings around the world. As a consequence, homogenization has brought the disappearance of each culture's building traditions. Homogenization has broken the link between society and its building traditions and the latter ceased to be an active influential factor on the way people build. Undoubtedly, the validity of local building traditions has yielded architecture that is in most cases inappropriate to the complex nature of an area's cultural norms and environmental conditions in a number of ways.

Firstly, the purposefulness of the vernacular architecture' construction was lost. Every single

element of a vernacular building was put together in a specific way for a reason, leaving at the same time a sense of openness for evolution to happen. This idea of the purposeful interrelation of elements was evident in a great range of scales; from the relationship of all the building elements that comprise a small dwelling (micro) to the relationship of buildings within the whole settlement (macro) and the relationship of all of the above to their environment. This characteristic is something which the majority of the contemporary designs miss. As a consequence, in the course of time most of the contemporary buildings will prove conceptually and visually incompetent to compare with the timelessness of vernacular buildings. The reason for that being that these buildings will inevitably never feel rooted to their social nor their environmental context as they do not respond to them.

Secondly, modern societies tend to put a premium on originality and often this is done for no particular reason, rather than its own sake. This tendency is an effect of the extinction of the vernacular building traditions as a regulator in a culture's architecture and consequently modern societies think of vernacular traditions as something undesirable. However, this desire for originality in buildings sometimes produces results which are based on ill-thought responses to real life conditions of a place. Although this is a socio-cultural phenomenon of modern societies, it has a direct impact on the resulted architecture.

Thirdly, as technology progresses people's needs follow, creating needs that people possibly never had. Either because they were suppressed over the knowledge that they cannot be achieved (due to the lack of the necessary means) or simply because they were genuinely non-existent before people knew they could have them. The effect that this had in architecture was the gradual increase in the need of more complex buildings/briefs which could not be satisfied just by following the vernacular building traditions, making this way vernacular building traditions obsolete compared to the specialization of all the professions that emerged as a result of the technological advancement. The above statements are not to say that technology should be excluded from the process of designing and constructing buildings as it has become an integral part of the industry and claiming to do so would be naïve, nostalgic and more importantly unrealistic. Technology in respects to architecture needs to be used in search of ways of reinforcing the vernacular traditions rather than replacing them altogether. The idea of using both collaboratively is what should be the goal of every self-conscious designer.

2.4 Function is the dominant factor of vernacular architecture

One of the most important qualities of the vernacular and one that tends to get overlooked is the fact that the vernacular was born out of a need to necessitate a particular function or process that met with local requirements. Brunskill's (1987) work is seen to be at the forefront of vernacular literature and he specifically points out that 'the function of the building would be the dominant factor' (Brunskill, 2000: 27-28), for the catalyst to construct a vernacular building. He further adds, 'aesthetic considerations, though present to some small degree (would be) quite

minimal. Local materials would be used as a matter of course, other materials being chosen and imported quite exceptionally' (Brunskill, 2000: 27-28). This strengthens the argument that the vernacular followed function rather than form. Each vernacular building and the individual element were designed or created to allow for a specific process that met with cultural, climatic or other regional factors. The vernacular did not import international designs or styles and was emblematic of locality, region and context.

Vernacular architecture follows a strategic choice of site, and they respond to the area's micro-climatic conditions. The vernacular was produced to necessitate a specific function that was determined through cultural dynamics rather than rationalise justifications.

2.5 Adaptability and uniqueness

One of the most important attributes, as Lawrence (1983) suggests, is that 'no building is or is not vernacular for its own qualities but is so by virtue of those which it shares with many others, and the identification of vernacular buildings is very much a matter of relative numbers' (1984 cited in Mercer and Hutton, 1984:13). This means a vernacular building is not simply a bespoke or one off the product. It must form part of a collection or family of buildings, even with varying typologies, scales and functions.

Another vital quality a vernacular building must exhibit is the use of locally available resources. Wright (1941) wrote vernacular architecture was fixed 'into the environment, by people who knew no better than to fit them with native feeling' (1941 cited in Oliver, 2003:9). The available resources would have been directly linked to the region's climate, historical context, culture and local materials. This is what makes the vernacular so unique to its exact region. Vernacular architecture is constructed using locally sourced materials and they are built by their owners/occupiers or occasionally with the aids of specialists who are still members of the same community using intuitive knowledge which is handed down from generation to generation. Moreover, vernacular architecture's building traditions respond to the culture's social and economic environments and they evolve along with the culture's intuitive wisdom. Mercer (1975) described vernacular buildings as those that belong to a particular place and a particular time.

2.6 Architecture of the people, by the people, for the people

The term vernacular architecture is often not fully understood or misinterpreted. Many seem to assume that the vernacular of a specific region is limited solely to the most traditional and prevalent form, but in fact there are many interrelated and worthy attributes it must also evoke.

Rudofsky's (1964) suggests that the vernacular was Architecture without Architects, as the title of his book. It also has been argued by scholars such as Oliver (1987) that the very process of consciously designing a building is not vernacular, as it has to be 'the architecture of the people, and by the people, but not for the people' (Oliver 1987:14). To create vernacular architecture it

had to be an organic process. It was constructed and erected because the indigenous populace demanded it and they could construct it themselves using intuitive knowledge, without the need for skilled professionals or craftsmen.

Paul Oliver (1997) in his book: Encyclopedia of Vernacular Architecture of the World: Vernacular architecture comprises the dwellings and other buildings of the people. Related to their environmental contexts and available resources, they are customarily owner- or community built, utilizing traditional technologies. All forms of vernacular are built to meet specific needs, accommodating the values, economies and ways of living of the cultures that produce them.

2.6.1 Freedom to build

Since the beginning of the twentieth century, Modernism has encapsulated and declared itself within two slogan-like assertions: those of Adolf Loos, 'Ornament is crime' and Louis Sullivan, 'Form follows function'. Modernism became the political manifestation of 'progressive' thought. Although this 'progressive' tide coincided with the worldwide spread of uniform, tedious and uninteresting buildings and urban environments, it would be unfair to blame Modernism for this, as these undesirable consequences were mainly the result of profit-driven enterprises. Nevertheless, the distorted use of modernism has been regarded by many as a set of values and premises that lacks respect for cultural identity, historical continuity and climatic relevance. (Asquith and Vllinga, 2006: 98)

The reaction to modernism took many forms, perhaps the most influential reaction is vernacular architecture and the revitalization. As a result of the reaction, the 'Architecture of Freedom', a 'revolutionary' movement, became a widespread repudiation of any control. This was a denial of the need for political and planning control over building practices by the people themselves, who took the initiative to solve their own, primarily housing problems. This movement, based its discourse on vernacular architecture, generating vast settlements like the *favelas* and *barrios* in South America, the *basti* in the Indian subcontinent, the *prosfika* in Greece, the *bidon-villes* in the North Africa, the *Kampung* in Indonesia, and the *gecekondur* in Turkey, all of which took off in the aftermath of second World War as 'people's solution' for housing in rapidly urbanizing countries. (Asquith and Vllinga, 2006: 98-99) Recognition of the form of building as a solution that changed the incapable institutional (or, for that matter, Modern) architecture, one that did not cope with the dynamism of the vast post-war demand, found its catch phrase in John F.C. Turner's declaration: 'Freedom to build' (Turner, 1976).

2.6.2 NGO

A **non-governmental organization (NGO)** is an organization that is neither a part of a government nor a conventional for-profit business. (*Non-governmental organization*, 2016)

Usually set up by ordinary citizens, NGOs may be funded by governments, foundations, businesses, or private persons. Some avoid formal funding altogether and are run primarily by volunteers. NGOs are highly diverse groups of organizations engaged in a wide range of activities, and take different forms in different parts of the world. Some may have charitable status, while others may be registered for tax exemption based on recognition of social purposes. Others may be fronts for political, religious or other interest groups. (OMICS International, 2014)

NGOs are difficult to define, and the term 'NGO' is rarely used consistently. As a result, there are many different classifications in use. The most common focus is on 'orientation' and 'level of operation'. An NGO's orientation refers to the type of activities it takes on. These activities might include human rights, environmental, or development work. An NGO's level of operation indicates the scale at which an organization works, such as local, regional, national or international. (*Non-governmental organization*, 2016)

The term "non-governmental organization" was first coined in 1945, when the United Nations (UN) was created. The UN, itself an inter-governmental organization, made it possible for certain approved specialized international non-state agencies—*i.e.*, non-governmental organizations—to be awarded observer status at its assemblies and some of its meetings. Later the term became used more widely. Today, according to the UN, any kind of private organization that is independent from government control can be termed an "NGO", provided it is not-for-profit, non-criminal and not simply an opposition political party. (*Non-governmental organization*, 2016)

The main characteristics these diverse organizations share are non-profit-distributing, non-governmental, independent or self-governing, formal organization, public welfare, voluntary and legal. Their non-profit status means they are not hindered by short-term financial objectives. Accordingly, they are able to devote themselves to issues which occur across longer time horizons, such as climate change, malaria prevention or a global ban on landmines. Public surveys reveal that NGOs often enjoy a high degree of public trust, which can make them a useful - but not always sufficient - a proxy for the concerns of society and stakeholders. (IISD, 2013)

NGOs were intended to fill a gap in government services, but in China, NGOs are slowly gaining a position in decision making. In the interest of sustainability, most donors require that NGOs demonstrate a relationship with governments. State Governments themselves are vulnerable because they lack economic resources, and potentially strategic planning and vision. They are therefore sometimes tightly bound by a nexus of NGOs, political bodies, commercial organizations and major donors/funders, making decisions that have short-term outputs but no long term effect. NGOs often take up responsibilities outside their skill ambit. Governments have no access to the number of projects or amount of funding received by these NGOs. There is a pressing need to regulate this group while not curtailing their unique role as a supplement to

government services. (Devi, 2013: 133)

In Chinese rural reconstruction projects, NGOs serve as intermediaries between beneficiaries, government, international relief/development organization, volunteers and experts. NGOs can play important roles in facilitating the design and construction of high-quality, culturally appropriate housing; revitalizing and diversifying livelihoods; and reducing physical and social vulnerability to future disasters. Compare to the government, NGOs have a certain amount autonomy to make their decisions and keep their organizational philosophies.

2.6.3 Construction Cooperative

2.6.3.1 Community

The origins of **community** in contemporary English can be traced from *communis* (Latin), *comunete* (French), the definition from the dictionary meaning: 1. A group of people living together in one place. 2. (the community) the people of an area as a group; society. 3. A group of people sharing a religion, race, or profession: the scientific community, 4. A group of animals or plants living or growing in the same place. (Oxford University Press, 2016) Phillips, D. (1995) in the book *Looking Backward: A Critical Appraisal of Communitarian Thought* definite community as: A Community is a group of people who live in a common territory, have a common history and shared values, participate together in various activities and have a high degree of solidarity. The term *communis* in latin means common. The significance of community is a common concern. The sociologist Ferdinand Tönnies (1885-1936) in fourteenth century proposed the term *Gemeinschaft*, usually translated as community, means that a spontaneously arising organic social relationship characterized by strong reciprocal bonds of sentiment and kinship within a common tradition; also: a community or society characterized by this relationship. 1. An association of individuals having sentiments, tastes, and attitudes in common; fellowship. 2. *Sociology*. A society or group characterized chiefly by a strong sense of common identity, close personal relationships, and an attachment to traditional and sentimental concerns. (Merriam-webster, 2013) The professor in Institute of Architecture and Urban & Rural Research of Taiwan University, Zhujiu Xia (1987) proposed that the concept of community is nostalgia of occident modern industrial society in the nineteenth century, because of the isolated and alienation of the modern society, people began to miss the romance and nostalgia of the past society, while community was assumed to be a happy life in a traditional society with emotional cohesion by the scholars at that time. The main characteristics of the community are that local, regional, traditional and common concern, which is similar with the term vernacular. In fact, in the architecture area, they have a deep connection.

2.6.3.2 Community participation in architecture

Community participation in architecture exists everywhere in the world. Before the mid-1950s in

western countries, making decisions of community was in the full control of planners and government officials. However, after the failures of several low-cost housing projects initiated by government around the world, the situation was changed. In some studies on urban slum-renovation projects carried out in the early 1950s, Edmund M. Burke found that these programs could not keep pace with the fast growing number of new squatter settlements. For example, the slum clearance activities of both Baltimore and Chicago redevelopment programs between 1950 and 1955 failed due to the simultaneous increase in the quantity of deteriorating housing. The pioneering works of theorists such as John F.C. Turner started a debate in the 1960s, on the direct involvement of communities in housing programs. In his book *Housing by People: Towards Autonomy in Building Environments*, Turner's thesis is that satisfactory goods and services, including housing, can only be produced locally through network structures and decentralizing techniques, which are crucial for the stability of our planet. Turner approaches his thesis by comparing examples of government initiated low-cost housing projects like Pruitt Igoe, with people initiated low-cost housing solutions like slums and squatter settlements. (Turner, 1977) Pruitt Igoe (1954-1976) was an award-winning low-cost housing project in St. Louis, which had to be completely demolished after a span of only two decades, due to its rapid physical and social deterioration. Turner argues that against such high budgeted failures, there exists a highly organized parallel system based on the ability of the people to house themselves in the form of squatter settlements and slums. Turner found that some of the materially poor dwellings were socially the best while some of the high standard dwellings were socially oppressive as seen in the case of Pruitt Igoe. Turner suggests a change in the government's approach towards housing; to stop building and managing houses, which it does "badly or uneconomically," instead should provide access to resources which the communities and people cannot provide for themselves (Turner, 1977).

Turner argued that housing is best provided and managed by those who are to dwell in it rather than being centrally administered by the state. In *Building Community* (Turner, 1988), he argued that neighborhoods designed with local groups worked better since people were experts on their own situations and should be given the 'freedom to build'. The professionals such as architects and engineers, act as enablers, who provide professional knowledge. (Spatial Agency, n.d.)

The principles of community participation are self-help, self-management, self-build, flexibility, participation and enablement. Community participation does not require huge investment initiated by the government but asks for a change of role of professionals and government, which is economical and sustainable. Whilst, 'Participation does not necessarily imply self-help home building by undernourished and overworked people without credit, with inadequate tools and poor materials' (Turner, 1977: 133), the most important function of community participation is making decisions. So the most of grassroots, NGOs, governments and funding agencies around the world have implemented community participation in making decision-making process of projects.

2.6.3.3 Chinese rural housing problems and construction cooperative

In most Chinese villages, the dwellings are divided basically into three groups, including the traditional dwellings over a hundred years, dwellings built with a mixture of lime, earth, sand and gravel in 1960s-1970s and newly built dwellings. The traditional ones are mainly built with traditional building techniques like Chuandou timber framing and local materials like timber, stone, earth, bamboo, etc. most new houses of the farmers are built by themselves, usually are brick masonry confined with concrete beams and columns. And the appearances and architectural plans are quite different from one another and not compatible as well. Usually the farmers build houses with help from their neighbors and relatives and the process of the construction is quite long without general planning. The orientation of the houses and the layout of the clusters are also in disorder so that waste of land is serious. Due to lack of technical guidance, the housing quality can't be guaranteed.

On the other hand, in order to improve the rural residents' living standard, a lot of exploitative housing projects have been implemented in rural areas by the government. These homes have become a life-long burden involving crushing mortgage payments for rural residents. People know to rise up and rebel against oppressive political hegemony. They require an innovative approach to tackling economic issues by offering a viable alternative in the form of a semi-independent construction system, housing cooperatives and a micro-finance supporting strategy.

The behavior of mobilizing neighbors to participate construction in agriculture society evolved into construction cooperative in industrial society, especially in rural areas. But in many remote villages in mainland China, the cooperative has not formed.

A cooperative ("coop") or co-operative ("co-op") is an autonomous association of people who voluntarily cooperate for their mutual social, economic, and cultural benefit.

Members of cooperatives are mostly from the socially vulnerable groups. They survive and develop in the fierce social competition with the unifying power, and they solve economic problems which can't solve with individual power in the production and life in the form of mutual assistance.

Cooperatives play an increasing role in economic development when facing the challenges from economic globalization. People in most of the countries and regions in the world enjoy the benefits of cooperatives. (*Cooperative*, 2016)

Construction cooperative is based on labor exchange system developing from traditional mutual help among neighbors. The construction cooperative was established by local construction 'experts' for ensuring the efficient labor exchange and granting the villagers' committees more autonomy in construction activities. **The financing mode** can be government grant, the

farmers' self-raised fund, and government-guaranteed loan. The relationship between the architects and residents in the construction cooperatives can be: the architects simplify the construction procedure, provide an open system and deal with technical issues, while the residents reflect living conditions, cultural environment and religious beliefs. Under this mechanism, a semi-autonomous construction system responding to cultural diversity is formed and residents' community awareness is established during the construction process, which may be a possible solution to Chinese rural housing problems mentioned above.

2.6.4 The Roles of activist architects in rural housing projects

The certified professional makes a fool of himself, and often does a great deal of harm to other people, by assuming that he knows more than the "uneducated" by virtue of his schooling. (Turner, 1972: 146-147) All that second- and third-hand information and intellectual exercising does for him, however, is to reduce his ability to listen and learn about situations significantly different from his own social and economic experience with consequences which can be tragic when he has the power to impose his solutions on those who are not strong enough to resist. John F.C. Turner (1972) in *Freedom to Build*.

'The modernist way of thinking prevents the architect from listening, asking questions and reaching out other sources of knowledge, which is, however, essential in this context.' Sandeep Virmani (Tauber, 2015: 53)

Today the world is an expert system, in the area of building environment there are various professionals like architects and planners. In this unpredictable and dangerous world, it's generally believed that these experts are the best for the people, due to their professional education. They are the authors of policies, guidelines and regulations transmitting what is the best housing for the people. And they make the tools for construction. Architects are appointed in order to ensure the realization of projects formulated by NGOs and government. However, many of the projects implemented are not sustainable. These formally trained experts make decisions and assign roles during the project. They take full charge of the projects and don't respect the context and the building culture they face with. Building professionals of vernacular architecture are craftsmen and user themselves. They are largely excluded from the process and distrusted. The formally trained experts of government, NGOs accused the vernacular building culture of producing 'weak', 'outdated' and 'unsafe' houses. And as a consequence, valuable vernacular building culture about how to use land, how to regard to local climate, appropriate construction materials, the layout of the house and the settlement are largely ignored. (Jigyasu, 2010) The complicated and diverse tasks in a rural environment are far beyond the experience of these architects, and their solutions are very often inappropriate. Hence, when these formally trained experts clash with vernacular building culture, the challenge is how to assign the right to the projects. In the case of community participation, the real 'expert', the craftsmen and user

themselves can be the organizer or even the teacher for architects and planners. In Habraken's (1961) opinion, it is not the architect who is allowing people to participate in housing process, something that they have been doing for ages. However, if people have the right and ability to house them is accepted then where does that leave the architects and planners in the process? N.J. Habraken (1961) believes that the role of the architect in such a situation can be determined by focusing on areas in which he or she can best benefit the project and by contributing in ways that no one else is capable of doing. The input of the architect also cannot be completely ignored in today's world of great possibilities. In fact, the experts and people are mutual teachers. In the new system, people make decisions, the professionals such as architects and engineers, act as enablers, who provide professional knowledge to help people to achieve their goals.

The theory of community participation in architecture started in the 1960s. It has stimulated a lot of successful community-based projects all over the world.

Taiwan architect Hsieh Ying-Chun played a role of designing housing prototypes and the industrial manufacturing in mass housing in many rural reconstruction projects. His housing prototypes are samples, people can learn from them and then create their own houses. The industrial manufacturing produces standard housing components, which provide access to building material resource for people.

Barefoot architect – Hassan Fathy (1900-1989)

New Gurna Village in Egypt was designed and built between 1946 and 1952 by the famous Egyptian architect Hassan Fathy. The Department of Antiquities commissioned Hassan Fathy to meet the challenge of providing a home for a poor community of 7,000 people. His solution did not require the machinations of the established building industry of concrete and steel. For New Gurna he utilized natural resources using mud-brick, a signature of adobe architecture, and features of Egyptian architecture such as enclosed courtyards and domed vaulted roofing. He worked with the local people to develop the new village, training them to make the materials to construct their own buildings with. He said that "One man cannot build a house, but ten men can build ten houses very easily, even a hundred houses. We need a system that allows the traditional way of cooperation to work in our society. I cannot cooperate in a city if the moment I get out of the door I am launched into the anonymity of millions. We must create new neighborhoods where I build for you and you build for me (i.e. I will have the same help from you when I come to build my house). We let the poor to participate in the construction process of protecting traditional cultural and adapt to the future development. In this process, they could accept our advanced construction technology more easily. For the low-cost construction, we need to add much more beautiful elements to reflect respect to human." (Hassan Fathy, 1980) In this way, he was able to provide an environment specific to the inhabitants' needs and revive decorative techniques that were quickly disappearing with the expansion of the Global Village. (Hwaa Irfan, 2004)

In his book *An Architect for the People*, American architect James Steele (1997) wrote of Fathy, “rather than believing that people could be behaviorally conditioned by architectural space, Fathy felt that human beings, nature, and architecture should reflect the personal habits and traditions of a community rather than reforming or eradicating them. While he was certainly not opposed to innovation, he felt that technology should be subservient to social values, and appropriate to popular needs”

3 The social movements, architectural critic and media interrelated with renovation of vernacular architecture and rural reconstruction in china

3.1 The social movements

The Rural Reconstruction Movement was started in China in the 1920s by Y.C. James Yen, Liang Shuming and others to revive the Chinese village. Yen's Ting Hsien (Ding Xian) Experiment in Dingzhou, Hebei and Liang's school at Zouping, Shandong, were only the earliest and most prominent of hundreds of village projects, educational foundations, and government zones which aimed to change the Chinese countryside. The rural reconstruction movement started by Dr. Yen continues to be active in Asia, Africa and Latin America. In the 1990s, several academics and social reformers in China started a New Rural Reconstruction Movement, with a station at Ding County. (*Rural reconstruction movement*, 2016)

New Rural Reconstruction is an intellectual current and social movement initiated by Wen Tiejun and other activists to address the crisis they saw in the Chinese countryside at the start of the 21st century. As of 2009, at its core there are several NGOs and academic institutions, dozens of rural cooperatives and associations, and hundreds of self-conscious participants (including academics, social workers, student volunteers, and grassroots activists). More broadly, the ideas and spirit of NRR have influenced a growing movement of rural experimentation, including many activists who do not use the term "NRR."

The NRR school is critical of the dominant current of utopian marketization, in which the market is seen as a solution to all problems. Instead, NRR supports the creation of rural cooperatives and other forms of cooperative social organization.

Wen hoped China's "people-centered scientific approach" and sustainable development would replace the earlier "vulgar growth" and "blind advocacy of consumerism."

In July 2003, grassroots activist Qiu Jiansheng founded the James Yen Institute for Rural Reconstruction. This became one of two national centers for NRR activities - mainly training student volunteers and grassroots activists on how to set up, run and support projects such as cooperatives. But in 2006 local authorities shut down the James Yen Rural Reconstruction Institute on the grounds that it had built an environmentally-friendly building without official approval, missed the annual inspection by the local government and advised farmers on petition matters.

In 2004 the other, still active national center - the Liang Shuming Center for Rural Reconstruction - was founded in Beijing by grassroots activist Liu Xiangbo, also with the support of Wen Tiejun. In 2005 Wen founded the Rural Reconstruction Center at Renmin University as an important institutional and economic base for the Liang Shuming Center and other NRR organizations and activities.

Other academic institutions, such as the Center for Rural Governance Studies at Huazhong University of Science and Technology, and other NGOs and networks, such as the Guizhou Association for Community Building and Rural Governance, identify with NRR, although some emphasize their differences from the current of NRR centered on Wen Tiejun and the Liang Shuming Center. Others, and an uncertain but certainly large number of grassroots experiments, have been influenced by NRR without using this term.

In recent years, the binary opposition between city and countryside is ever greater. The cities are like a magnet, attracting a lot of resource, talents and funds, develop rapidly. While the brain drain of countryside make it become more and more destitute, the tide of peasant workers migrating to cities like migratory birds, most of the young rural scholars from villages work in the cities, they only return home for the holidays. The uneven and uncoordinated development of urban and rural area make the social resource can't be allocated reasonably.

The growing wealth gap and natural disaster stimulate the awakening of the civic consciousness of people with vision, they have a strong aspiration to reconstruct rural place where 56% of Chinese people live. While the development of rural place was ignored in the early stage of Chinese Reforms and Opening. Facing with the fading of villages, many NGOs began to carry out the environmental protection and pay attention to the livelihood of rural China. In the 5.21 Sichuan relief, some NGOs obtained achievement in the reconstruction process, which have a reference value for community construction of rural place. The activist architects and NGOs attempt to explore the construction pattern for rural China, and they are in the early stage of experiment and theoretical research. (*New rural reconstruction movement*, 2013)

Presently there are some activists, architects and NGOs working for rural China construction, such as Hao Lin, Hsieh Ying-Chun, Ren Weizhong, Liu Jiakun, ARDA China, Habitat for Humanity China, Wu Zhi Qiao (Bridge to China) Charitable Foundation, etc.

3.2 Architectural critic - Zhu Tao

Zhu Tao, the assistant professor of the Department of Architecture, the University of Hong Kong, is a very active architectural critic in the public sphere. He concerns the rural construction in China. He wrote a series of articles after the 2008 Sichuan earthquake, '*Inspiration of Taiwan 9.21 post-earthquake reconstruction*', '*New School Project Proposal*', '*Guard Hu Huishan Memorial*', '*Beautiful Houses of Shigeru Ban*', etc. and a series of articles discussed on community

participation in architecture, such as the interview cooperated with the Southern Metropolis Daily, *'One Support Another – Architecture, Media and Civil Society Construction'* (2008), *'From Mobilize the Masses to Citizens participation and From Quarter development to Community Construction'* (2009), etc. He can clearly discern the problems embedded in China's reality. He is courageous to speak out and to criticize, with his own unique and penetrating views. He concerns humanity and social responsibility in Chinese built environment. His work promotes the development of vernacular building culture and rural community China.

3.3 Southern Metropolis Daily

Southern Metropolis Daily (SMD) is a Chinese prominent mass media, which commits to promoting Chinese built environment. In 2007 it held the Chinese Architectural Thoughts Forum which provides a pure platform for Chinese building culture communication.

In 2008 SMD organized the China Architecture Media Awards (CAMA) collaborated with eight main Chinese architecture magazines, The Architect, Time + Architecture, World Architecture, Domus China, New Architecture, World Architectural Review, Urban Environment Design, and Architecture Technique. With the bold slogan *'Toward a Civil Architecture'*, the CAMA Committee offers a series of biannual architecture awards, in an attempt to *'promote architecture's engagement in China's construction of the civil society'*. The *'Civil Architecture'* according to Awards Charter refers to the architecture works concern people's livelihood, housing, community participation in architecture, built environment, public space, vernacular building culture, humanity, etc.. There were five awards, Young Architects Award was obtained by Standard Architecture group, Residential Architecture Special Award was awarded to Tulou Commune in Nanhai city Guangzhou Province, Committee Special Awards was got by Taiwan's architect Hsieh Ying-Chun, 94-year-old architect and educator Feng Jizhong obtained Outstanding Achievement Awards, Maosi Ecological Experimental Primary School of Wu Zhi Qiao (Bridge to China) Charitable Foundation won the Best Architecture Award. All of these award winners contributed to the rural construction in China, and they concerned the development of community participation and vernacular building culture.

In 2009 SMD held the second Chinese Architectural Thoughts Forum discussed on Community Participation in architecture, which was open to all of the people. In 2010 SMD held the second CAMA, the outstanding Achievement Award was obtained by Han Pao-teh; Residential Architecture Special Award for two winners, Tianjin Zhongxin Eco-city Builder's Apartment and Protection and Reconstruction of Ahol Neighborhood in Old District of Kashi City; Young Architect Award's winner is Fu Xiao; Architectural Critic Award's winner is Zhu Tao, Committee Special Award was awarded to Wu Zhi Qiao (Bridge to China) Charitable Foundation. Compare to the first CAMA, the quantity and quality of the entries were much more and better, there were more than 100 self-building projects in the entries, is five times of the first session. Shi Jian, the architecture

viewer, commented: “in a sense, the second session of CAMA is a comprehensive survey of outstanding architecture in the mainland, Taiwan, Hong Kong From 2009 to 2010.” CAMA became the most influential architecture award in the mainland, Hong Kong and Taiwan in that year.

After having experience of holding two sessions successfully, SMD decided to host Chinese Architectural Thought Forum and CAMA biennially. The power of media gradually played an important role, to challenge the power of government.

4 Renovation of Yi people's vernacular architecture in Liangshan Yi

Autonomous Prefecture, Sichuan

4.1 The structural and decorative art of Liangshan Yi people's vernacular architecture

There is the largest population of ethnic Yi nationally in Liangshan Yi Autonomous Prefecture. Yi people have unique vernacular building culture. Though the beautiful and carefree wooden structures and the decorative art, with the tradition of carpentry that created this vernacular architecture of Liangshan Yi People, they express their history, rituals, and lives.

4.1.1 The siting and the plan of Yi people's villages

The Yi ancestor in the Daliang Mountains usually selected the cove in the half-mount as the location of the villages. The economic resource of Liangshan (the Daliang Mountains) Yi people is agriculture and animal husbandry. The main farm livestock is horse and sheep who eat the grass on the hillside. The main crops are upland crops such as buckwheat, potato and corn, which are suitable for planting on the mountain slopes. In Liangshan Yi tradition, the upper hillside is for pasture; the lower hillside is for farming; the cove in the middle is for habitat, which is the common mode for siting. Owing to the high altitude, the rainfall in the cove is a little. Hence, there is no disaster caused by rain. The hillside where the village locates in usually faces south, to get more sunlight. The Gutuo Village is in the cove, as shown in Figure 1 (Xu, 2012).



Figure 1 The overlook to the homes in Gutuo Village, Meigu County (Xu, 2012)

Because the main economic resource, the animal husbandry exhausts the soil quickly, each home should have sufficient land for pasture. Lianshan Yi people don't have the traditional of multiple generations under one roof, the families are small and independent. And they outline the limits of their homes. So, normally, there is a far distance between each home, from dozens of meters to hundreds of meters.

Since the scattered layout of the buildings in the village, the roads are not defined by the boundaries of the building complexes, on the contrary, they connect these independent homes. The system of the roads is very complex, there are a lot of classifications; the main roads ran through the village; the branches are distributed into the farmland. The village usually has a plain field as the public space.

The main water resource is from well, underground spring and streams in the mountain. So that nearby river is not an important factor for siting.



Figure 2 The home of a carpenter's family in Gutuo Village, Meigu County (Xu, 2012)

The traditional houses in Meigu County remained intact during the earthquake. Figure 2 shows a home of a carpenter's family in Gutuo Village of Meigu County (Xu, 2012), it is traditional Chuan-dou type wooden structure, the walls are made by mud, the foundation is made of stones, and the roof is covered with small wooden planks on which stones were laid. It is the type of ordinary Yi houses. The houses are warm in winter and cool in summer.

Every home has a courtyard for keeping animals, as shown in Figure 3 and Figure 4 (Xu, 2012)



Figure 3 (left) The Courtyard of the carpenter's home in Gutuo Village (Xu, 2012)

Figure 4 (right) The pig barn in the Courtyard of the carpenter's home in Gutuo Village (Xu, 2012)



Figure 5 The front gallery of the carpenter's home in Gutuo Village (Xu, 2012)

Figure 5 shows the front gallery (Xu, 2012). Liangshan Yi people usually put firewood, dry clothes and the grains in the galleries.

4.1.2 Beautiful designs of the timber frames

Chuan-dou type is one of the Han people's traditional timber structures. It is usually used in the rural homes in the south of China. The homes have good seismic performance, which is mainly achieved by the frame deformation and friction slip.

In former times, the building culture of Yi people in Daliang Mountains was influenced by Han people. They began to construct Chuan-dou houses combining with their own building culture.

The Chuan-dou timber structure of traditional Yi residence in Daliang Mountains is very similar to the ordinary Chuan-dou structure. The rows of columns are set according to the amount of the purlins in the direction of the depth; the purlins are set on the columns; there is no rafter in the frame of the roof, the load on the roof transmits directly to the purlins and columns; the penetrating tie connects each row of columns in the direction of the depth, forming the roof trusses; the purlins connect the roof trusses. The roof truss is always used for the gable ends and the partition walls. In some elaborate Chuan-dou frame, there are lintels set under the purlins to connect the roof trusses.

The water-buffalo-horn-gong is a unique structural element of interlocking wooden brackets, one of the most important elements in traditional Yi architecture. It is a structural network that joins the pillars and columns to the purlins. The water-buffalo-horn-gong consists of the horizontal cantilevers (Gong) and the vertical suspension columns ending with the water buffalo horns. The water-buffalo-horn-gongs are used to decrease the amount of the columns in the living room and support the eaves. As shown in Figure 10, the use of the water-buffalo-horn-gongs decreases a row of columns in the living room (Hou, 2004: 109). The part of the frame with water-buffalo-

horn-gongs used in the living room is called Shanjia. Figure 6 shows the water-buffalo-horn-gongs in the living room of the home (Xu, 2012). And Figure 7 shows the water-buffalo-horn-gongs for supporting the eaves (Xu, 2012).



Figure 6 (left) Interior Shanjia timber frame of the carpenter's home in Gutuo Village (Xu, 2012)

Figure 7 (right) the cornice of the carpenter's home in Gutuo Village (Xu, 2012)



Figure 8 the cantilevers and the suspension column (Hou, 2004: 116)

Chuan-dou timber frame is a lightweight frame. In Yi people's Chuan-dou structure homes, the diameter of the columns is 20-30cm; the section dimension of the connected frame (Chuanfang) is changing from 6cm x 12cm to 10cm x 20cm.

The connection of the wooden pieces is the mortise and tenon joint. Joinery is a major focus, and craftsmen cut the wooden pieces to fit so perfectly that no glue or fasteners are necessary.

Figure 9 shows the typical form of Chuan-dou timber frames in traditional Yi residence. (Hou, 2004: 102)

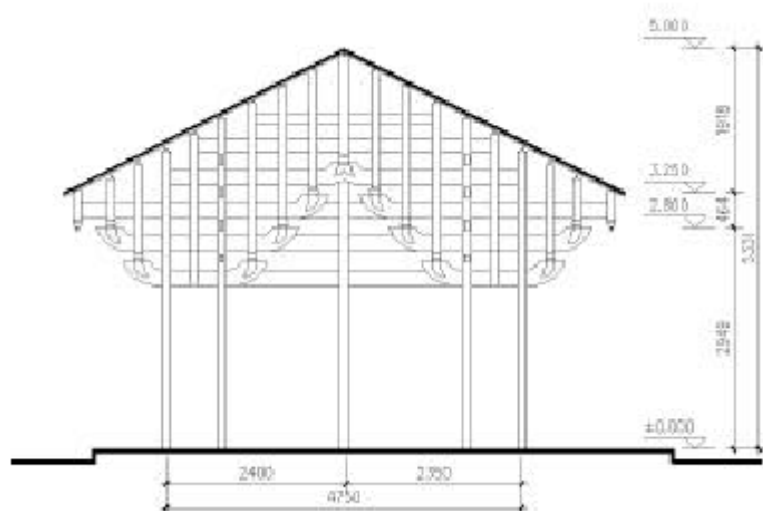


Figure 9 The plan and section of the re-assembling Shengzha residence in Liangshan University (Hou, 2004: 102)

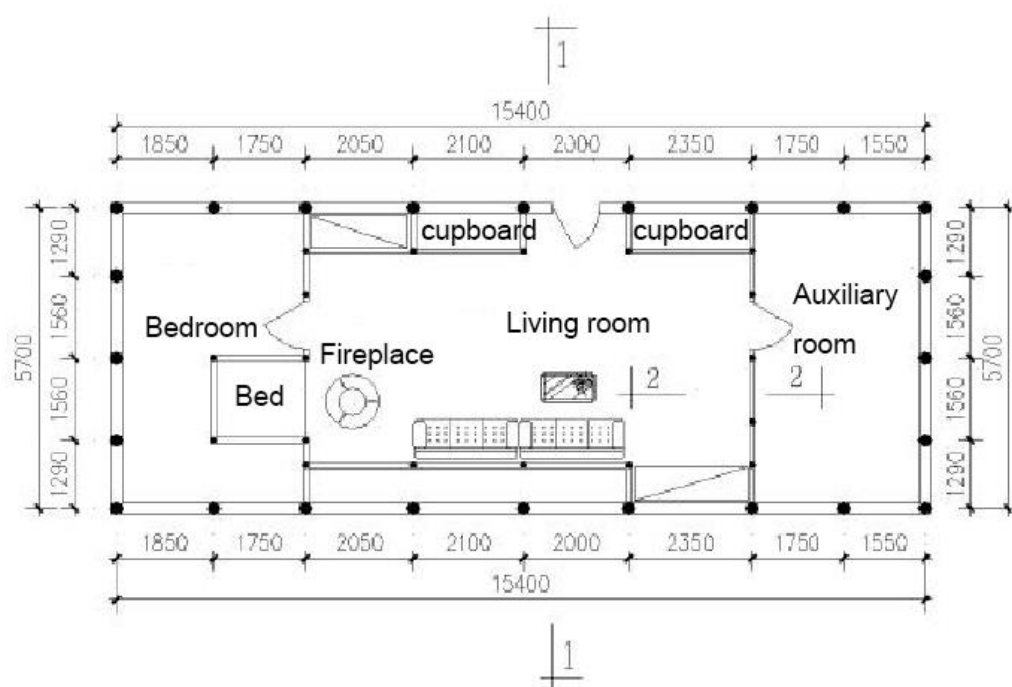


Figure 10 The plan of Dazelaji's home in Meigu County in YINUO area of the Daliang Mountains (Hou, 2004: 109)

Timber frame decorations

Yi people have totem adoration for the bamboo and water buffalo. They like to use timber frame decorations like water buffalo horn and bamboo knot. For example, the suspension column decoration is like water buffalo horn as shown in Figure 11 (Hou, 2004: 131). And the water-

buffalo-horn-gong decorations are like buffalo horn and bamboo knot, as shown in Figure 12 (Hou, 2004: 116).



Figure 11 (left) Ornaments like water buffalo horns of the suspension column (Hou, 2004: 116)

Figure 12 (right) Ornaments like water buffalo horns and bamboo knot on the cantilevers and the suspension column (Hou, 2004: 116)

4.1.3 The roof creating mysterious lighting effect

Figure 13 shows the roof covered with small wooden planks on which stones were laid. (Xu, 2012)



Figure 13 The roof of the carpenter's home in Gutuo Village (Xu, 2012)

The production process of wooden planks

In Yi people's tradition, the homeowners can't make wooden planks for themselves, they should ask his neighbors who live upper than them in the mountains for help. The participators should harvest the trees growing above the location of the new houses in the mountains. The whole process of making wooden planks should be done on the harvesting site. In order to remain the

grain, they peel off the 23-cm-thick pieces in the direction of the grain, and cut them into the size of 150-200cm length and 30cm width. Then they make a fire in the forest, and bake the wooden planks to a little blackish. They bury the roots of the cut trees with thatch and earth, and pray for the tree god's blessing on the new home. Finally, they take the wooden planks to the site of the new home.



Figure 14 Laid stones on the roof (Hou, 2004)

There is no rafter in the roof. The wooden planks are laid directly on the purlins. After laying all the planks, the wooden poles will be put on each row of planks, then the stones will be laid over the poles, as shown in Figure 14 (Hou, 2004). The laid stones can prevent the strong wind blowing the wooden planks off. The wooden planks have natural curvature, because they are peeled off in the direction of the grain. The participators consider fully the unique curvature of each plank when laying them on the roof. The stagger arrangement and the undulating form of the planks ensure the roof not leaking, meanwhile, allow sunlight entering through the gaps between the planks, forming a mysterious lighting effect as shown in Figure 6 (Xu, 2012). In addition, in some roofs there are translucent tiles used to increase natural lighting.

Yi people in Daliang Mountains value highly the wooden planks which are thought to be attached by the blood and the breath of the family. People turn over the planks every two years, to keep them dry on both sides. Yi people moved frequently in history. When moving, they were certain to bring the planks and passed them down from generation to generation, even if thrown the whole wooden frame. In the latest survey, the oldest wooden planks have a history of more than 100 years. It is the evidence that Yi people cherish their wooden planks.

The roof is light and has a beautiful texture. The grains of the wooden planks forming the natural rain gutters contribute to drainage. The process of making wooden planks demonstrates the

respect for nature. The culture of wooden planks is an outstanding part of Yi people's building culture.

4.1.4 The rammed earth wall and the decorative wooden wall

The walls in traditional Yi residence are not load-bearing. There are two types of walls: the rammed earth wall and wooden wall.

The rammed earth wall

The enclosure of the traditional Yi residence usually is rammed earth wall, the thickness 25-30cm. The wall coating is a mixture of buffalo dung and mud. The climate in the Daliang Mountains: winters feature mild days and cool nights, while summers are very warm and humid. There is a great seasonal temperature difference. Temperature deformation coefficient of the buffalo dung is close to the earth. And it is used to prevent the rammed earth wall from cracking. The rammed earth wall has good thermal performance. The massive enclosure walls keep the home cool in summer and warm in winter.

The wood wall

Wood board has worse thermal performance than rammed earth, so it is usually used for the partition wall. The wood wall decorations show the homeowner's wealth and status. Figure 15 shows the wood wall of the carpenter's home in Gutuo Village (Xu, 2012). In some Yi people's homes, the middle part of the front walls is decorative wood walls.



Figure 15 The door and the wood lattice window in the wooden wall, the carpenter's home in

Gutuo Village (Xu, 2012)

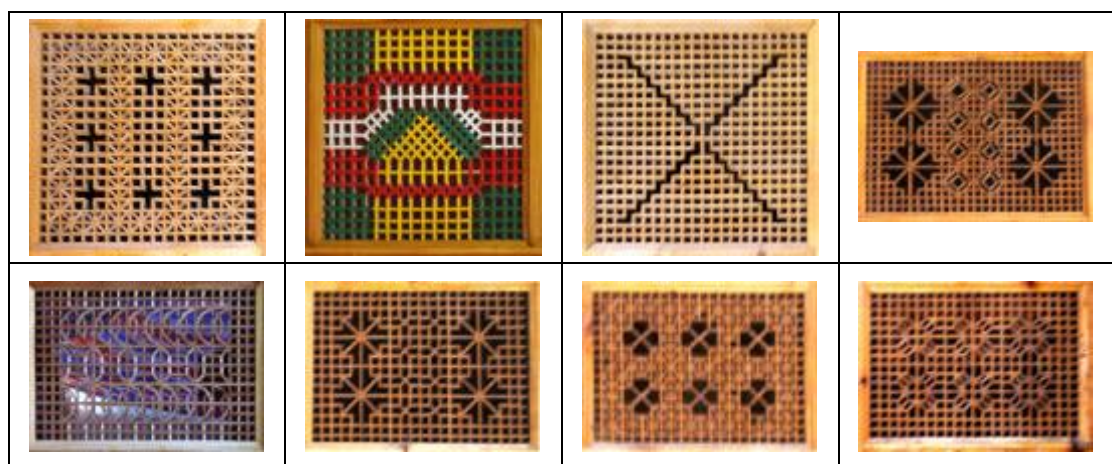


Figure 16 the full wood wall of the middle concave gallery and its pattern (Hou, 2004)

4.1.5 Decorative wood lattice window

The wood lattice windows in the partition walls are decorations. The wood lattice windows for lighting and ventilation are always on the wooden front wall, above the door. The craftsmen fix the tiny wood pieces in the wood window frame without using nails. The window dimension usually is about 0.5m × 0.9m. The wood lattice always remains its natural wood color. Some Yi people like to paint colors on it now.

The wood lattice windows are designed by the homeowners or the craftsmen. They are, very often, the repeating simple geometric designs or abstract patterns of the crops such as corn and wheat or the natural objects such as mountain, river and flower. The designs have various meanings such as wealth and fame. Figure 15 shows the wood lattice window of the partition wall (Xu, 2012).



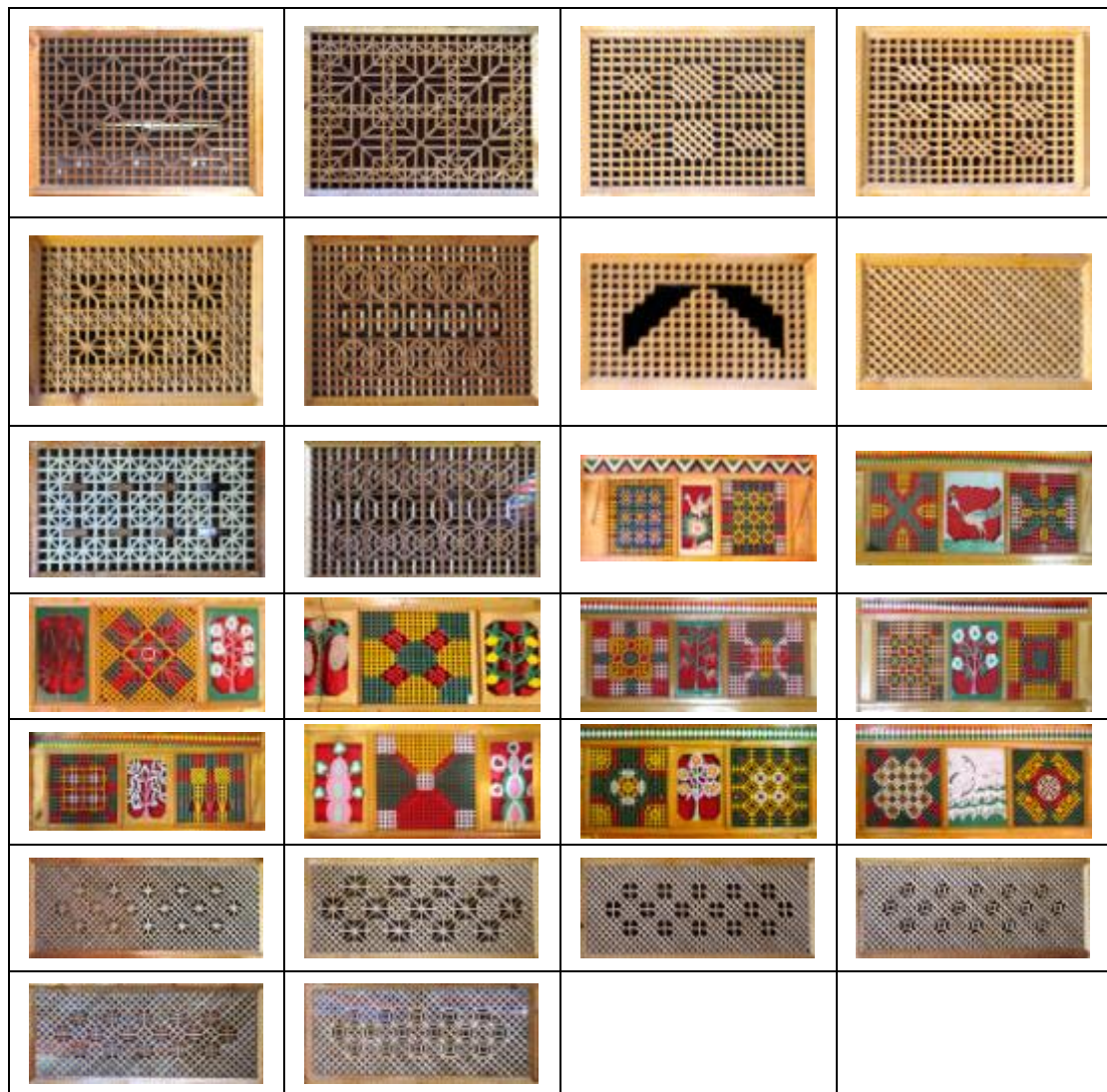


Figure 17 Decorative wood lattice windows in the partition walls (Hou, 2004)

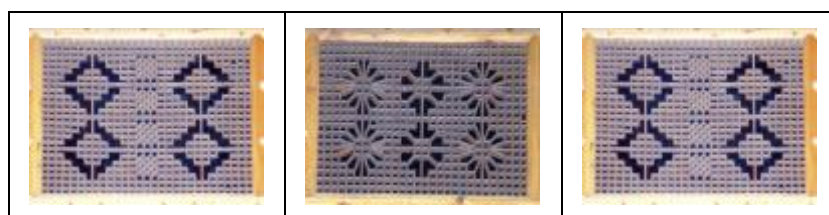


Figure 18 The wood lattice windows in the front walls (Hou, 2004)

4.1.6 Lighting and ventilation

There are a few openings in the Yi traditional homes. The small lattice window rarely appears in traditional Yi residence. The door also is very low, and has a high threshold. Hence, the house is a bit dark and damp. The design is mainly influenced by the environmental, social and cultural factors.

The average altitude of the Daliang Mountains is 2000-2500 meters. The climate of the plateau is very harsh. There is an extreme temperature difference between day and night, great seasonal temperature difference, strong wind and ultraviolet radiation. The traditional Yi residence usually is located in the mountainside exposed to the harsh climate. In order to shelter people from the harsh environmental conditions, the door is the main element for lighting and ventilation, and there is seldom or even no window; all the openings are on the front wall and there is no opening on the back wall, to prevent the howling draught from impacting the indoor temperature.

In Yi people's culture, the window and the door also are the access for the ancestral spirits and ghosts. In order to limit them access, they decrease the openings as much as possible.

On the other hand, in order to defend against the frequent clan conflicts, Yi people in Daliang Mountains had to reduce openings to increase the security of their homes.

The unconventional lighting ways

As mentioned before, the gaps between the wooden planks on the roof allow sunlight entering, forming a mysterious effect of indoor lighting. In addition, the translucent tiles are also used to strengthen lighting.

The only **artificial light source** is the fireplace.

4.1.7 The arrangement of rooms

In the home of the carpenter, the bedroom and the auxiliary room are on the two side of the living room. The entrance door is closer to the auxiliary room. The auxiliary room is divided into two floors, the ground floor as corral and utility room, and the second floor as grain warehouse or the bedroom for children. The ladder to the second floor is in the living room. The second floor can be seen as an extending space of the living room. The partition wall of the master bedroom just reaches the bottom of the water-buffalo-horn-gongs. The upper space of the home is connected. Figure 10 shows the plan of Dazelaji's home in Meigu County in Yinuo area of the Daliang Mountains (Hou, 2004: 109), which is the typical plan of traditional Yi homes.



Figure 19 The Fireplace of the carpenter's home in Gutuo Village (Xu, 2012)



Figure 20 The meat hanging on the wooden beam over the fireplace, the carpenter's home in Gutuo Village (Xu, 2012)

Figure 19 shows the fireplace in the living room (Xu, 2012). The fireplace is nearby the bedroom, away from the entrance door. It consists of three stones, called 'Guozhuang' (pot hanging over a hearth). It is the center of the home life. People like to chat, cook, have a meal and drink teas around it. The meat hanging on the timber beam was smoked over the fire. The smoked meat is the traditional food of Yi people. The timber frame smoked over the fire are more resistant to infection and decay. The fireplace is considered as a symbol of the family. And they think that the

flame from the fireplace is closely related to their fate and the fortune. Various ritual activities are carried out around the fireplace.

4.1.8 The traditional building community

The villagers in Meigu County have a traditional building culture passed down from generation to generation. The housing process was under the full control of people for years in the village. The villagers were experts on their own situations. They know how to select a location, choose orientation, arrange rooms and use appropriate construction materials. The siting and the planning of the village are managed by the intellectuals of the village. The homeowners manage their own housing projects. They design and build the house with the assistance of the local carpenter and his neighbors. After the construction is finished, the homeowners will invite the neighbors and the carpenter to dinner and pay them. In the case of community participation, building a house is not a heavy financial or physical burden for the villagers. On the contrary, the building process is a festival for the participators. The villagers learn construction skills from the carpenters, and they communicate the designing together. All of them can gain knowledge and enjoyment, and the building community also develops in the process.

4.2 An unsuccessful post-earthquake reconstruction project in Zhaojue County



Figure 21 Landscape of Zhaojue County (Xu, 2012)

Figure 21 shows the landscape of Zhaojue County (Xu, 2012). Zhaojue County is nearby Meigu County. The houses in the Hot Spring Village of Zhaojue County were damaged severely in the earthquake.

Liangshan Yi Autonomous Prefecture, Sichuan Province were attacked by the 5.12 Sichuan earthquake in 2008. The local government initiated a low-cost post-earthquake reconstruction project for housing villagers of Hot Spring Village. The decision maker authorized by the government abandoned the original village, and decided to rebuild the village on the agricultural land, the construction waste disposal of the original village was left in abeyance.



Figure 22 The New Hot Springs Village in Zhaojue County (Xu, 2012)

Figure 22 shows the location of the new village. (Xu, 2012) The siting of the new village is inappropriate. It not only occupies the agricultural land, but also is unsafe. It is located on the floodplain. Flood, mudslides and landslide usually hit this area. However, the new houses can't resist these natural disasters.



Figure 23 A New House Being Built in Hot Springs Village, Zhaojue County (Xu, 2012)

The new house is a blend of solid masonry construction and timber frame. Figure 23 shows the new house being built (Xu, 2012). There is no earthquake-resistance structure like ring beam and reinforced concrete column. The 18-cm-thick brick walls are very weak. There is no adequate beam/column joint tie between the roof and the wall. The roof was just put on the top of the wall. The structure of the new housing have a serious safety problem, is can't resist earthquake.



Figure 24 A New House Being Built in Hot Springs Village, Zhaojue County (Xu, 2012)

Figure 24 shows the roof being built. (Xu, 2012) The roof consists of timber frame, reeds and cement tile. The small cement tiles were just hung on the timber battens, which would be very dangerous in the earthquake, people would be killed by the falling tiles. The tiles also would be blown off by the strong wind. In 2008 winter snow storms, the roofs of many new houses were destroyed by the accumulated snow.



Figure 25 (left) The Eaves of a new House in Hot Springs Village, Zhaojue County

Figure 26 (right) The Roof of a New House in Hot Springs Village, Zhaojue County (Xu, 2012)

The Figure 25 and Figure 26 show the eaves and ceiling of the house. (Xu, 2012) There are many gaps between the roof and the wall. The poor construction quality leads to the poor soundproofing and thermal performance. The Daliang Mountains has a mild climate. Winters feature mild days and cool nights, while summers are very warm and humid. Due to the thin brick walls, the single glazed windows, the gaps between roofs and walls and the poor window and door seals, the new houses cannot meet the basic thermal requirement. The villagers living in the new homes have to use air-conditioners in summer and charcoal in winter, the energy consumption is very high, and they cannot afford to pay the energy bills.



Figure 27 The steel cooker in the separated kitchen (Yixing Xu. 2012)

In Yi people's tradition, the fireplace in the living room is the center of the home life. However, in the new houses, there is no fireplace in the living room, it is replaced by a separated kitchen with a steel cooker as shown in Figure 27 (Xu, 2012). The design doesn't respect to their lifestyle, no wonder the villagers do not like the new dwellings.

Sitting on the ground is the Liangshan Yi people's custom. The officials thought that it was not clean and civilized. They initiated the 'Chair Project' forcing the people to sit on the chair to improve the sanitary condition and civilization. The officials wanted to foist their beliefs upon people. However, his goal was not reached. Because the first and perhaps key factor is the

villagers' hygiene consciousness, not sitting ways. The officials can develop the health education and sanitary facilities, but not the 'chair Project'. In most villages, the officials make the wrong decisions due to their ignorance and unchecked right. (Xu, 2012)



Figure 28 (left) the New Houses in Hot Springs Village, Zhaojue County (Xu, 2012)



Figure 29 (right) a New House and the Village Office Being Built in Hot Springs Village, Zhaojue County (Xu, 2012)

Figure 29 shows the new home and the village office being built in Hot Springs Village. (Xu, 2012) The office building is a blend of masonry construction and reinforced concrete frame structure. There are earthquake resistance designs like ring beam and reinforced concrete column. The construction quality of the office is much better than the homes, which demonstrates a wealth inequality between government and villagers. The wealth gap also would lead to a psychological gap between government and villagers.



Figure 30 (left) The New Hot Springs Village (Xu, 2012)



Figure 31 (right) the Street of Hot Springs Village (Xu, 2012)

Figure 30 and Figure 31 show the street of Hot Springs village (Xu, 2012). The streets between the homes are narrow. The courtyards between houses are dark and damp; space is not sufficient for keeping animals. The courtyard walls are not independent. However, Liangshan Yi people think highly the independence of the territoriality; each home should have their own land for pasture

and farming, and they would like to outline the limits of their land. The planning of the new village doesn't respect their lifestyle. There is no public space for villagers. All the houses are the same. The sustainable factors of local vernacular house were absent in the 'modern' habitat design. The only use of local traditional design is the yellow pattern on the walls. The decoration is recognizable as a symbol of iconic architecture, which is a superficial portrayal of the vernacular. The infrastructure of the new village is very poor. There is no water supply and drainage system, electricity grid system and garbage recycling system.



Figure 32 Another post-earthquake reconstruction village nearby Hot Springs Village in Zhaojue County (Xu, 2012).

Figure 32 shows another post-earthquake reconstruction village nearby Hot Springs Village in Zhaojue County (Xu, 2012). All the reconstruction projects in Zhaojue County are similar to the Hot Springs Village, were initiated by the government. The end-users cannot participate in the reconstruction process. The whole process is controlled by experts appointed by the government. However, the architects and planners didn't respect the context and the vernacular building culture of Yi people. The design is inappropriate. And the construction quality is very poor. Not long afterward the villagers can't stand living there anymore, they moved one after another.

4.3 Liangshan Children's Hope Home under construction

Xu Yixing designed Liangshan Children's Hope Home. There is no large-scale public building in Liangshan Yi people's history. The construction techniques of Liangshan Children's Hope Home is inherited from the Yi people's traditional residence. It is Chuandou timber frame and rammed earth construction. The builders are local craftsmen. There is a traditional fireplace consisting of three stones (Guozhuang) in the courtyard and hall, which expresses Yi people's special ideology and spirit. Because the traditional craftsman is rare, the project is hard to go forward. The traditional construction is labor-intensive, but only a few people can working on site due to the population decline in the rural area. So, the construction duration of the project would be very long.



Figure 33 Liangshan Children's Hope Home under construction (Aya Arch, 2005)



Figure 34 Effect drawing of Liangshan Children's Hope Home under construction (Aya Arch, 2005)

4.4 Conclusions

The vernacular building culture is in a difficult position.

The globalization of modern architecture has marginalized many vernacular building cultures, we even don't have enough time to record the disappearing culture. However, most people in the city still think the process is advanced; they also force forward it. Influenced by such dominant culture, gradually, the Yi people in Daliang Mountains began to lose confidence in their building culture. Facing with the great wealth gap between city and village, some villagers began to think that everything in the city is the best. They abandoned all their traditions, and attempted to copy all the things in the cities. However, due to the lack of knowledge and the low economic level, the 'modern' houses built by them is poor in design and construction quality. A big part of the houses damaged in the earthquake were the 'modern' houses. At the same time, the traditional culture is vanishing, because there is few people would like to carry on it. Hence, the development of vernacular culture is plunged into darkness.

Improving the tradition

The negative consequence to abandon tradition is the disappearance of cultural characters and national identity. Our attitude towards tradition should be inheriting it critically, developing its good aspects. Only in this way we can keep our historical wisdom and access to new

development.

The traditional building culture is not just a heritage. We have to learn the wisdom of our ancestors and update it to adapt to the contemporary society. So the essence of improving tradition is to improve the awareness of human. Obviously, the traditional technology has a lot of defects. However, it also has a great potential. It has high performance and low-cost when compare to concrete construction. So we have to change the awareness of villagers and let them inherit their own culture. In the past times, every village has their intellectuals like squire and landlord. Nowadays, the intellectuals only exist in the big city. Most villagers have a low education level. They don't have enough scientific awareness. In order to recover their confidence in the vernacular building culture, the government, NGOs and fund agencies can help to set up building community, training program and provide a good condition for local carpenter to survive. The rural reconstruction is great opportunity to develop new vernacular culture combining with modern culture, which maybe can bring good influence on modern city construction. Firstly, we should develop a new pattern for rural construction research; the local carpenters will be the leaders; enhancing the co-operation and integration among villagers, carpenters, activist architects and NGOs. Secondly, launching more community projects and training course to provide people with opportunities to learn theories and practice them in reality. These people can become the potential force to the development. Finally, we should develop it in cities. In this way, we could integrate the vernacular culture in the mainstream values instead of being marginalized; the young generations in the cities would respect our tradition and discovery the ancient wisdom.

The problem of Civil Serves System

In ancient China, the emperors ruled the country by virtue rather than law and might. The virtue is based on the Confucianism. All the officials were selected through the imperial examination. They formed the civil serves system. The government didn't set up the special judicial system and tax office, even no standing army. The country was controlled by a small government. In traditional society, the scale of 'county' is twice times bigger than today's 'county'. The county magistrate was the lowest official position, and was the only official in the county. He managed all the affairs including administration of justice, public order, conscription and tax revenue. The most villagers have never seen a government official for a lifetime. The management area of the government is limited. Many specific activities were managed by the 'squires'. The formation process of a 'squire' is: a villager passed the imperial examination to become a civil official; after retirement they came back to their hometown, these retired civil officials were called 'squires'. They are vital links between the government and the villagers. On the one hand, they were loyal to the emperor, as believed in Confucianism; they helped the active officials to keep the social order. On the other hand, they were also loyal to the interest of the community, because in Confucianism there is a concept which is 'To a state, the people are the most important, the state comes second, the ruler is the least important.' Once the ruler lost his goodness, it will provide the rationality for the resistance. Due to their scholarship and moral integrity, the villagers

respect and trust them greatly. The villagers let them make the major decision of the village development such as rural planning and irrigation projects. In the case, they were the leaders of the community.

Nowadays, the group of squires has disappeared. The intellectuals of the villages have gone to the cities. At the same time, the development of the vernacular cultures was impacted by the globalization. In the case, many villages have lost their beliefs and have fewer morals. From the perspective of building culture, many of them also have lost the aesthetic appreciation and traditional building techniques. On the other hand, the right of the government is stronger than that of ancient empires. There are township head and village head for the position of county magistrate. The village heads were authorized to manage all the affairs of the village by the government. The future of the villages relies on them. However, most of them don't have the ability to handle the job. Because they were originally ordinary people in the villages, they were chosen by vote. The villagers voted them because of friendship or kinship. So the village head usually is from the local largest family, but not the ablest man. The villagers don't trust them, while the government authorized too much right to them. Furthermore, the code is incomplete, and an effective mechanism for code enforcement is absent in China. It could be argued that the right of the officials is unchecked. In many cases, the officials make wrong decisions and foist their individual beliefs on the villagers. Due to their messy management or even abuse of power, a lot of conflicts and tragedies happen. In the architecture area, the village planning was done by the squires and the building community consisting of villagers and craftsmen in the traditional society; the housing was managed by the homeowner and built by the building community. While nowadays, the village planning and the housing are fully managed by the village head. In the village reconstruction projects, they can foist their willing upon on the villagers. This deficiency in governmental oversight is linked to several related factors, such as the lack of technical control and supervision, problems with the legal framework, low engineering fees, and improper regional construction practices. Hence, the failed reconstruction project in Zhaojue County is only one instance out of many. For the development of the rural area, a complete code, an effective mechanism for code enforcement and an effective civil serves system are essential.

The role of architects in the rural reconstruction project

After the Sichuan earthquake of 2008, the formally trained professionals authorized by the government have permeated habitation policy and the whole reconstruction process. Due to their professional education, the public and private agencies believed that they are the best for the people. They were the authors of numerous policies, guidelines and tools on and for the rehabilitation program, constructing and transmitting what 'sustainable' and 'people-oriented' housing is. However, their involvement as a part of political agenda propagating did not bring a better future. The unsustainable nature of many of the projects which were implemented is particularly surprising. The architects were assigned responsibilities unquestioningly during the project and were irrespective of Yi people's building culture. The government representatives accused that the traditional house of Yi people was 'weak', 'unsafe' and 'outdated'. They ignored

largely the traditional know-how with regard to land-use, local climate, appropriate construction materials and layout of the house (arrangement of rooms). The decision makers from public and private agencies conceived post-earthquake reconstruction as an opportunities to modernize rural settlement with the support of formally trained 'experts'. The architects were assigned responsibility for numerous tasks such as the planning and the designing for new habitats and new village office, for developing construction technologies, for managing contracts, and for supervising the quality of construction. Above all, they were expected to realize sustainability with regard to culture, technology and environment as well as earthquake-resistant settlements and houses.

They enjoyed a good reputation at the institutional level, their expertise had been legitimized by the agencies provided housing. However, according to the villagers, the projects failed on a fundamental level, such as the location and orientation of the house, the plot and the house, the arrangement of rooms, the appearance of the house, the choice of the construction materials, and the quality of the construction. For many architects working in a rural post-earthquake environment was a new experience. The myriad and diverse tasks were far beyond their experience, and the solutions provided by them were thus, very often, inappropriate. In fact, in this environment, craftsmen are rural expert, they have developed appropriate habitat designs and technologies over centuries. The decision maker relegated them to a level unworthy of consideration. Before these government initiated projects, it is the craftsmen who enjoys an excellent reputation at the village level, and whose skills is the leading force in habitat design and construction. The majority of the villagers would have chosen the craftsmen during reconstruction if they had had a free choice. Because the craftsmen design and build based on wishes and needs and he does good quality work.

The villagers' considerations demonstrate that formally trained architects do not provide adequate expertise for many challenges during reconstruction. More precisely, the villagers' voices demonstrate that calling in formally trained architects, unquestionably assigning them roles and responsibilities, irrespective of the peculiarities and abilities of the vernacular building culture can have fatal consequences.

NGOs and activist architects

NGOs and activist architects are a supplement for government administration. Once they obtained the support of the village head, they can play a role as the 'squires'. Currently, NGOs in China is an emerging group, while they are still in its infancy. After the 5.21 Sichuan earthquake in 2008, the NGOs began to develop quickly, new NGOs sprang up all over the country. Since then, the role of NGOs in the social life, especially in the earthquake relief has become more and more important, they are a unique force in efforts to make a change in China. In village reconstruction area, they cooperate with the activist architects to develop vernacular building culture and construction community. Building community is not a fresh conception in China; it existed in our traditional building culture for thousands of years. In recent decades, it was interrupted by the

modern business model. Setting up construction community in today's business environment is a challenge. Various groups and activist-architects like Xu Yixing have begun their experiments in China, although currently there is almost not a theoretical research on the community participation pattern adapting to China.

To construct the village successfully it has to be an organic process. It should be built because the villagers demand it and they can construct it themselves using intuitive knowledge, with the aids of skilled craftsmen or professionals. The villagers can best provide and manage the housing responding to the culture's social and economic environments rather than the government. The local building community should be given the freedom to build. The professionals such as architects planners and engineers, act as enablers, who provide professional knowledge.

On the other hand, the self-building community in rural place doesn't mean that we should over working with inadequate tools and poor materials. We should use the advanced technology or industrial manufacturing to improve the vernacular building culture. It is the most important work for the professionals. The communities should act as decision-makers. The NGOs, governments and funding agencies should support the community participation in decision-making process.

5 Liu Jiakun's installation artwork 'Rebirth Brick' and post-earthquake reconstruction in Sichuan

5.1 Liu Jiakun's installation artworks of 'Rebirth Brick'



Figure 35 Venice Architecture Biennale 08: 'Rebirth Brick' in the Chinese Pavilion (Designboom, 2008)

The theme of the Chinese pavilion in Venice Architecture Biennale 08 was 'Ordinary Architecture'. There are a group of works which dealt with this theme and were divided into two parts – 'Negotiation' and 'Daily Growing'.

The sub-theme of 'negotiation' deals with what everyday negotiation is all about – negotiation. On a daily basis, architects are constantly making deals and negotiating with the client, the budget, the site, the code and other conditions and constraints. Negotiation is driven by a sense of social responsibility and is always strategic. In light of the tremendous tragedy of the Sichuan earthquake, the projects in this section look beyond building technologies and socio-economic systems, returning to the most important negotiation, that which is between the architect and nature itself.

Included in the 'negotiation' section of the pavilion was the project 'Rebirth Brick', a material manufacturing project by architect Liu Jiakun. The project began in June of 2008, one month after the earthquake in Sichuan, China, as a response to the need for individuality and self-sufficiency. Material debris left as a result of an earthquake is collected, sterilized and recycled to be used as

an aggregate. It is mixed with wheat branches which are in abundance through rural villages, waiting to be processed. The wheat branches are cut up into smaller pieces and act as a reinforcing fiber, mixed in with the debris and concrete, to create light-weight bricks to be produced on a small scale using a semi-manual leveraging tool which is widely used in china by the local crafting industry. Metaphorically it is not only a 'physical' rebirth but also a spiritual one, taking something from a situation of turmoil to one of renewal.

'Ordinary Architecture' deals with buildings which have authorization, raising the issue of ordinary architecture in a time when china serves as the world's playground for architects. The pavilion questions the authority's destructive approach to urban planning, severing the link between contemporary architecture and tradition. In a sense, ordinary architecture can also be seen as a form of activism. (Designboom, 2008)



Figure 36 Material debris and wheat branches waiting to be mixed and made into bricks (Designboom, 2008)



Figure 37 Completed bricks drying (designboom, 2008)



Figure 38 Close-up of the tooling machine used to produce the bricks (designboom, 2008)



Figure 39 Up-close you can see the debris and wheat branches which has been mixed with concrete to produce the bricks



Figure 40 (left) the aftermath of the Sichuan earthquake (designboom, 2008)



Figure 41 (right) an abundance of wheat branches waiting to be used (designboom, 2008)



Figure 42 (left) the machine used to breakdown the rubble from aftermath of the earthquake (designboom, 2008)



Figure 43 (right) a worker producing bricks (designboom, 2008)



Figure 44 (left) a worker prepares concrete to combine the aggregate and wheat branches. (designboom, 2008)



Figure 45 (right) the bricks are polished and any excess material is removed. (designboom, 2008)

Liu Jiakun showcases his “Rebirth Brick’ project’ at the 2011 Shenzhen & Hong Kong Bi-City Biennale of Urbanism\Architecture. The blocks were part of the Chinese pavilion at the Venice Architecture Biennale 08.



Figure 46 (left) Bamboo is used instead of steel bars to reinforce the structure (GABA, 2011)



Figure 47 (right) Built structure using the recycled material (GABA, 2011)



Figure 48 Material connections and details (GABA, 2011)

5.2 Application of 'Rebirth Brick' for the Post-earthquake Reconstruction Projects in Sichuan

'Rebirth Brick' was actively promoted for reconstruction in 2008 Sichuan earthquake-stricken zones. The bricks have been used to build and reconstruct the damaged areas, creating new meanings to the ideas of renewable materials and the regeneration of a community.

The prices of the conventional building materials rose in the disaster zone. For example the price of the red brick is about 180 yuan/m³. While the price of the 'Rebirth Brick' is about 80 yuan/m³. (Liu, 2008) The 'Rebirth Brick' is a new type light-weight brick. There was no corresponding national standard. It has been tested temporarily according to the national standards of the concrete hollow blocks. Its compressive strength met the standard, other performance testing will take time. The 'Rebirth Brick' also can be produced with the large automatic machine, which could be used for load-bearing walls.

Before the earthquake, the load bearing masonry construction was very popular in the area. It essentially consists of the vertical elements, the brick masonry walls and brick columns and the horizontal elements, the floor slabs, beams and roofs, which could be made of reinforced concrete.

Its bearing walls were not well constructed and confined by reinforced concrete columns and beams. In Chinese seismic design code, the entire load bearing concrete structure have to be strengthened with the ring beam and the structural column which are made of reinforced concrete. However, the seismic performance of the load bearing masonry buildings has been very poor in 2008 Sichuan Earthquake. One of the underlying reasons is the absence of a system of checks and balances to prevent local officials, government-appointed builders, and inspectors from siphoning funds out of public construction projects, especially schools and hospitals. Many buildings were not designed or built according to the seismic design code. In many damaged buildings, the floors slabs were made of precast concrete panels, and there was no ring beam or reinforced concrete column. The precast concrete panel and unreinforced masonry construction were proven 'serial killers' in many Earthquake worldwide. On the one hand, Development in the region has progressed farther and farther back into the mountains, toward the quake-prone area. The rate of building in the area was astonishing. On the other hand, the buildings were not able to resist earthquake. Hence, the buildings became a culprit; five million people have become refugees in 2008 Sichuan Earthquake.

In the earthquake relief, creating an earthquake-resistant structure to withstand any future temblor in the quake-prone area is a real challenge. Due to economical reasons, many advanced techniques are not required to improve the earthquake resistance of rural Chinese housing.

Liu Jiakun suggested people build reinforced concrete frame construction with infill masonry. In order to reduce the cost of construction as well as technique required for the construction, the span between two columns is up to 4m, the houses have at most 2 floors. The walls are not load bearing, which could be built with the 'Rebirth Brick' or other cheap materials. And its partition walls can be arranged flexibly; the houses also could be extended easily in the future. Thus when the residents had saved enough money they would expand the buildings. It was a pragmatic and participative solution.

Unlike load-bearing masonry construction, the reinforced concrete frame construction, does, however, require a certain level of technology, expertise, and workmanship, particularly in the field during construction. The engineers could design a series of simple housing prototypes and teach people the construction technique, in the case, the simple low-rise residential buildings could be self-constructed. Without the intervention of the construction team appointed by the government, the villagers can save a lot of money.

Due to its relatively low cost compared to other materials such as steel, Reinforced concrete

frame with masonry infill walls could be used extensively in most of the post-earthquake rural area. Furthermore, the construction cost and the techniques required of reinforced concrete frame construction are similar with the well-built load bearing masonry construction with ring beam and structural column. And the seismic performance of reinforcing concrete frame construction is better than load-bearing masonry construction, due to its load capacity, ductility and structural capacity.

Reinforced concrete frames consist of horizontal elements (beams) and vertical elements (columns) connected by rigid joints. Beams and columns are cast in a single operation in order to act in unison. Reinforced concrete frames provide resistance to both gravity and lateral loads through bending in beams and columns. Requirements related to design and detailing of reinforced concrete frame buildings in seismic zones is more focused on the proportioning and detailing of beams, columns, and joints with the objective to achieve a certain amount of ductility in addition to the required strength rather than on the strength—that is, on providing adequate strength in structural members to resist the lateral seismic forces. Ductility is one of the key features required for the desirable seismic behavior of building structures. It can be defined as the ability of a material to stretch (deform) significantly before failure. Steel (and some other metals) exhibit ductile behavior. For example, a metal paper clip can be bent back and forth without breaking. However, other materials are brittle (the opposite of ductile). A piece of chalk will break as soon as we try to bend it. In reinforced concrete, concrete behaves like chalk, whereas steel reinforcement behaves like a paper clip. Therefore, steel reinforcement has a key role in ensuring ductile behavior of reinforced concrete structures in earthquakes. (Yakut, n.d.)

The reinforced 'Rebirth Brick' infill walls could be built after the completion of the reinforced concrete frame construction. They act in unison with the columns and the beams to increase the strength of the reinforced concrete frame. And careful detailing and the joints ties are required to ensure that bonding between the walls and the reinforced concrete frame under earthquake loads is effective.

The seismic detailing design is to ensure that the amount and distribution of steel reinforcement are adequate. The principles and rules of seismic detailing of reinforced concrete structures have been emerging over time and are mainly reflected in seismic provisions of building codes.

In the 2008 Sichuan Earthquake, seismic performance of some reinforced concrete frame buildings also has been quite poor, even when subjected to earthquakes below the design level prescribed by code. One of the underlying reasons is the absence of an effective mechanism for code enforcement in China. This deficiency in governmental oversight is linked to several related factors, such as the lack of technical control and supervision, problems with the legal framework, low engineering fees, and improper regional construction practices. When one or more such factors are present during construction, the built structure does not comply with many aspects of the design. As a result, its seismic resistance becomes inadequate, with the consequence that

unpredictable damage or failure results when subjected to loads below the code-prescribed levels. The situation can be improved by the self-building community, when the homeowners dominate the building program with the aids of the engineers and government, the shoddy construction could be avoided.

In the self-building process, people used various building techniques of infill walls and finishes, including vernacular building techniques, as shown in Figure 49 and Figure 50. (Liu, 2009)

The self-building houses in the post-earthquake areas:

The various infill walls:



Figure 49 The building materials of the walls could be stones (left), bamboo plywood (middle), mud plastering on woven bamboo (right), (Liu, 2009)

The various finishes:



Figure 50 The finishes of the enclosure: Ceramic tiles (left), Mortar (middle), Paint (right), (Liu, 2009)

Hu Huishan Memorial, a reinforced concrete frame building with 'Rebirth Brick' masonry infill walls constructed by Jiakun Architects in 2009:



Figure 51 (left) Hu Huishan's Memorial in the woods (Baan, 2009a)



Figure 52 (right) The entrance of Hu Huishan's Memorial (Baan, 2009b)



Figure 53 (left) Interior of Hu Huishan's Memorial (Baan, 2009b)



Figure 54 (right) Interior of Hu Huishan's Memorial (Baan, 2009a)



Figure 55 The round skylight (Baan, 2009a)

Hu Huishan Memorial House is located in a piece of forest next to the “512 Exhibition Hall” of Jianchuan Museum Cluster in Dayi town, Dayi county, Sichuan Province. This memorial was donated and constructed by Jiakun Architects in 2009, for Hu Huishan, an ordinary female student from Juyuan Middle School who was buried in the Wenchuan earthquake. The Hu Huishan memorial takes its prototype from the pitched roof makeshift tents frequently used in the quake-stricken area. Its scale is similar with the tents. The site area is 58m²; the building area is 19 m². It is reinforced concrete frame building with ‘Rebirth Brick’ masonry infill walls. The floor

in the exterior and interior is paved with red bricks, and the exterior wall is plastered with mortar, just as those commonly seen in the houses at quake-stricken areas. The interior wall is painted into pink which is the girl's favorite color. A ray of light from a round clerestory, makes this small space pure and charming. Inside the memorial, the sidewalls are displaying a few remembrances which record Hu Huishan's short life: photos, schoolbag, notebooks, deciduous tooth, umbilical cord... Her life didn't leave much trace on the society. (Liu, 2009)

The promotion of the 'Rebirth Brick'

The 'Rebirth Brick' program has been practiced since June of 2008, the supply of the semi-manual operation is not adequate to the demand for the reconstruction. So a lot of small-scale manufacturing plants have been set up to produce them. Liu Jiakun cooperated with some fund agencies to serve the villagers in the reconstruction. The first pilot village is located in Mianzhu, Sichuan. The greatest difficulty that they faced is obtaining enough money. The received government grants were only a quarter of the funds needed for reconstruction. And the donated money was not in place timely because of various reasons. In the case, the 'Rebirth Brick' was budget-priced. Additionally, all raw materials could be obtained easily, and the entire manufacturing process is very simple. Everyone can produce them easily.

In order to communicate better with the villagers, Liu was stationed in the village and put aside his cultural background. He said: 'the identity of architect cut no ice with the villagers. They have their own ideas about their homes, we can't foist our beliefs on them. And we also faced a lot of problems with the civil service system. The architects were just working as volunteers. In the case, the most important thing is to hold on to the last.' (Liu, 2008) Finally, the villagers accepted to use 'Rebirth Brick'. The prototypes of the reinforced concrete frame construction designed by Liu also were welcomed. The approach was implemented successfully in multiple reconstruction residential projects a few years after the earthquake.

Along with the post-earthquake reconstruction program was done by piecemeal, Liu Jiakun looked into further applications of the product and alternative production methods. The 'Rebirth Brick' approach was applied in the green industry reusing the building waste. Because of the species diversity, complete specifications, quality, reliability, credibility and low price, they have become mass-produced and are being used in the construction of residences and public buildings such as Shuijingfang Museum, West Village Basis Yard (Figure 59) and Novartis Institutes for Biomedical Research in Shanghai.



Figure 56 Various species and specifications of the 'Rebirth Brick' (Lin and Liu, 2015)

There is always demolition and reconstruction in the cities, especially in China. There are always a large amount of building wastes which could be used as raw materials for 'Rebirth Brick'. The techniques have been developed, if there were policy support, media publication, storage yards for building waste and funds, the 'Rebirth Brick' could be popularized.



Figure 57 The house built by the villagers with 'Rebirth Brick' (Lin and Liu, 2015)

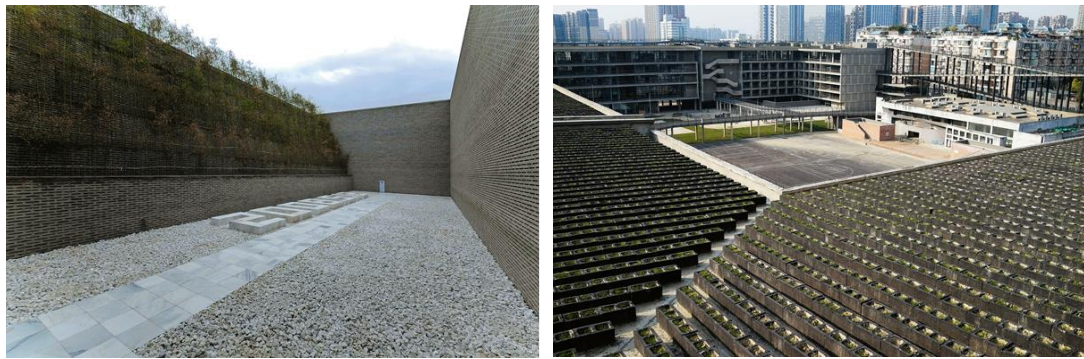


Figure 58 (left) application of the 'Rebirth Brick' – Earthquake Relief Exhibition Hall (Lin and Liu, 2015)

Figure 59 (right) application of the 'Rebirth Brick' – West Village Basis Yard (Lin and Liu, 2015)

5.3 Conclusions

In the 2008 earthquake relief, the architect Liu Jiakun volunteered for the rural reconstruction. He was stationed in the villages and promoted 'Rebirth Brick' and the prototypes of the reinforced concrete frame house. The 'Rebirth Brick' has a lot of advantages: the manufacturing process is simple, quick, low-cost and environmental-friendly; the products have species diversity, complete specifications, good quality, reliability and credibility; everyone could produce it without restrictions of the patent. The prototypes of the reinforced concrete frame housing are earthquake-resistant, low-cost, low-tech, and suitable for self-building.

Local officials and residents in general tend to favor his activity that promises benefits to the area. Liu has become fairly well known for his 'Rebirth Brick' through word-of-mouth and media coverage.

Liu cooperated with funding agencies to provide building techniques training for the villagers. The trained villagers organized the self-building community. Their initiatives and creativeness were stimulated in the reconstruction due to the community participation. In this way the villagers could play a constructive role, but not just relied on the government passively. As a result the reconstruction projects were successful.

The prototypes designed by Liu is an open system which can be combined with various building techniques. Liu encouraged people to use vernacular building techniques, because they are eco-friendly and economic in general. There are abandoned bamboo, wheat-branch and straw in Sichuan Province. People used these materials to make infill walls of bamboo weave plastered with mud, bamboo plywood, etc. The activity was beneficial to the development of the vernacular building culture.

The houses also could be extended easily in the future. Thus when the residents had saved enough money they would expand the buildings. It was a pragmatic and participative solution.

The popularity of 'Rebirth Brick' also is beneficial to the development of the rural industry. Due to the increasing demand for the rebirth bricks, the supply of the individual semi-automatic products couldn't meet it. Hence, the villagers set up small-scale manufacturing plants. Along with the post-earthquake reconstruction program was done by piecemeal, the 'Rebirth Brick' approach was applied in the green industry which is reusing a large amount of the demolished building waste in the cities. So far many residential buildings and public buildings in the cities have been built with 'Rebirth Brick'. In this way, the rural industry influenced the urban construction.

As mentioned before, due to a serious brain – drain and aging, many villages inland are fading. In the traditional society, there were a group of intellectuals - 'square' leading the villagers. The government power was limited. The square's presence also balanced the government power. But nowadays the group has disappeared and the government power becomes much stronger. There is not any effective mechanism for law enforcement and against corruption and power rent-seeking. In most villages, it is common that the incompetent officials with unchecked power make wrong decisions. In the 2008 Sichuan Earthquake, seismic performance of the buildings in rural area has been quite poor, even when subjected to earthquakes below the design level prescribed by code. One of the underlying reasons is the absence of an effective mechanism for code enforcement in China. This deficiency in governmental oversight is linked to several related factors, such as the lack of technical control and supervision, problems with the legal framework, low engineering fees, and improper regional construction practices. When one or more such factors are present during construction, the built structure does not comply with many aspects of the design. As a result, its seismic resistance becomes inadequate, with the consequence that unpredictable damage or failure results when subjected to loads below the code-prescribed levels. Many villagers were killed by the jerry - built projects, the public opinion in an uproar. It was not until then the architects returned to the problem of the rural poor, reprising design as a tool of politics. There are a lot of architects volunteered in the rural reconstruction after the earthquake. Liu Jiakun is just one of them. Often, they had strategic solutions but needed to lobby the politicians to realize them - which is what makes them activist architects. They worked in disadvantaged communities, with minimal budgets and in conditions of desperate need. They also faced with the issues of the official service system, law and cultural conflict with the villagers.

This activist-architecture like Liu Jiakun requires an expanded skill, working in the community. They have to get to know the communities they want to work in, understand their needs and make them participants in the process.

However, activist architects can't begin large-scale projects on their own. The housing is just a

small challenge. The real problem is to construct public transport, cottages, schools, hospitals, and communities. The rural residents suffer from the poor infrastructure than they do from the quality of their homes. Architects can help to organize communities for the rural residents, but self-organization has its limitation - a community can build themselves homes but they cannot build themselves a transport network.

Secondly, the intervention of one reconstruction village can stimulate change, but it needs to be implemented at a larger scale to improve the quality of the whole post-earthquake rural reconstruction. Though architects can be mediators, but they cannot work lonely as charity workers.

So, they need a political commitment. A complete code, an effective mechanism for code enforcement and against corruption and rent-seeking and an responsible civil serves system are essential. Architecture is a social act and they provide the exemplars that prove to governments that change is within their grasp. In an ideal world activist architects would not have to exist but, since the world is far from ideal, we need them badly. (McGuirk, 2014)

6 Straw Bale Ecological Housing of ADRA International

6.1 ADRA International

The Adventist Development and Relief Agency (ADRA) is a global non-governmental organization present in 125 countries providing sustainable community development and disaster relief without regard to the political or religious association, age, gender, race, or ethnicity.

ADRA has been working in the People's Republic of China since 1998, addressing poverty alleviation through microcredit, health, disaster preparedness and environmental issues. Their key program is the introduction and extension of safe, healthy, sustainable, and energy-efficient straw bale construction practices. (McGill, 2009)

6.2 Straw Bale Housing Projects in North-eastern China

An innovative straw-bale construction method is being used in north-eastern China to build houses and other public buildings using waste rice straw. ADRA China has implemented its straw bale housing projects in north-eastern China since 1998. Their work consists of social marketing among homeowners, and training of construction workers. Technical assistance in building straw bale homes also was provided as needed. So far over 600 straw bale homes and three schools have been completed, and hundreds of people including local officials, builders, architects and homeowners have taken part in the building technical training. To date over 2,000 people have benefitted from the projects.

Although straw bale building has been in use for more than a century, its use in construction has recently gained popularity due to the superior insulation it provides, which makes straw bale homes more economical and energy efficient than traditional homes. The benefits of the program include significantly reduced coal consumption and CO₂ emissions, affordable warmth and less respiratory disease for residents, much greater resistance to earthquakes and savings of precious top-soils due to reduced brick production.

Project Description

Aims and Objectives

- To develop safe, healthy, sustainable and energy efficient construction practices in north-eastern China.

- To use locally available materials, designers, management personnel and builders throughout the project.
- To create buildings that are healthy, comfortable, safe, affordable, durable, energy efficient and aesthetically and culturally appropriate.

There is a severe need for adequate housing in rural north-eastern China, exacerbated by an environmental refugee population fleeing desertification who suffers from cold, poverty and the attendant illnesses. Existing housing is frequently damaged by snow, flooding, or earthquakes. A significant proportion of the 160 million population lives in substandard and dangerous housing. The popular traditional mud, rock and brick houses are poorly insulated, uncomfortable and offer little protection from the severe cold of the region with temperatures as low as -40°C . Consequently, people use a large portion of their income on sulfurous coal for household use, leading to respiratory problems.

Traditional houses are also extremely dangerous in this seismically active region of the world. The structures, often built of mud, rocks, rubble and brick, lack even minimal toughness or connectivity, and readily collapse even in minor earthquakes. The families are forced to rebuild (with meager resources) a house that is even poorer in quality than the original. As a result, residents are prone to suffer illness and bad health especially during the winter. Any new construction is carried out using locally made bricks, which adds to the removal of scarce topsoil, which increases the already high levels of air pollution and topsoil removal and provides poor seismic performance.

To solve a problem like this you need the empowerment and enthusiasm of the local people, thoughtful design consultation, and innovative ideas. Kelly Lerner, architect of One World Design, with the Adventist Development and Relief Agency (ADRA), was able to combine these elements in her straw-bale housing project, using a locally available waste material to provide safe, sustainable, energy- and cost-efficient housing. (Tipping Mar + associates, 2005)

Straw-bale construction is especially well suited to the local conditions and climate in north-eastern China. It was first tested in China with a 1998 pilot project building a straw-bale school, designed by Kelly Lerner and Tipping Mar + associates, after a relatively minor earthquake had destroyed the original brick school. The new school has been very successful with much-reduced heating costs and it has withstood a subsequent earthquake of 5.6 on the Richter scale while other buildings around it collapsed.

To be effective, sustainable technologies must be adopted and widely used. To be adopted they must be easy to use and fit well with existing local materials, technologies, and skills. The hybrid building systems use:

- Rock foundations (with or without a grade beam depending on seismic activity and local practice).
- Full-width brick columns, flanking window and door openings.

- Straw bale in-fill between posts.
- A concrete bond beam.
- Locally produced trusses. (Lerner, 2004)

Structure and building material

For the ensuing housing project, Kelly Lerner and Tipping Mar had to apportion resources wisely because of the very limited construction budget (an estimated \$4 per square foot). Straw is locally available and light enough to be transported without heavy machinery. To seismically safeguard the structures and keep cost in control, Tipping Mar designed with a very light touch. Starting at the bottom, the traditional dry-stacked stone bases were replaced with cement grouted and reinforced stone footings. Steel wire ties were cast into the foundation, and extended into brick columns and straw-bale walls. The typical load bearing, mud-mortared brick walls were replaced with cement-grouted brick columns with wire reinforcement. The columns are connected with a continuous reinforced concrete bond beam. The bond beam formed the platform for the simple timber and wood roof. Wire ties and anchor bolts, along with steel straps and nails, tied the entire roof together. Earthquake resistance is provided by straw-bale infill walls. They are plastered with cement stucco and reinforce with wires.

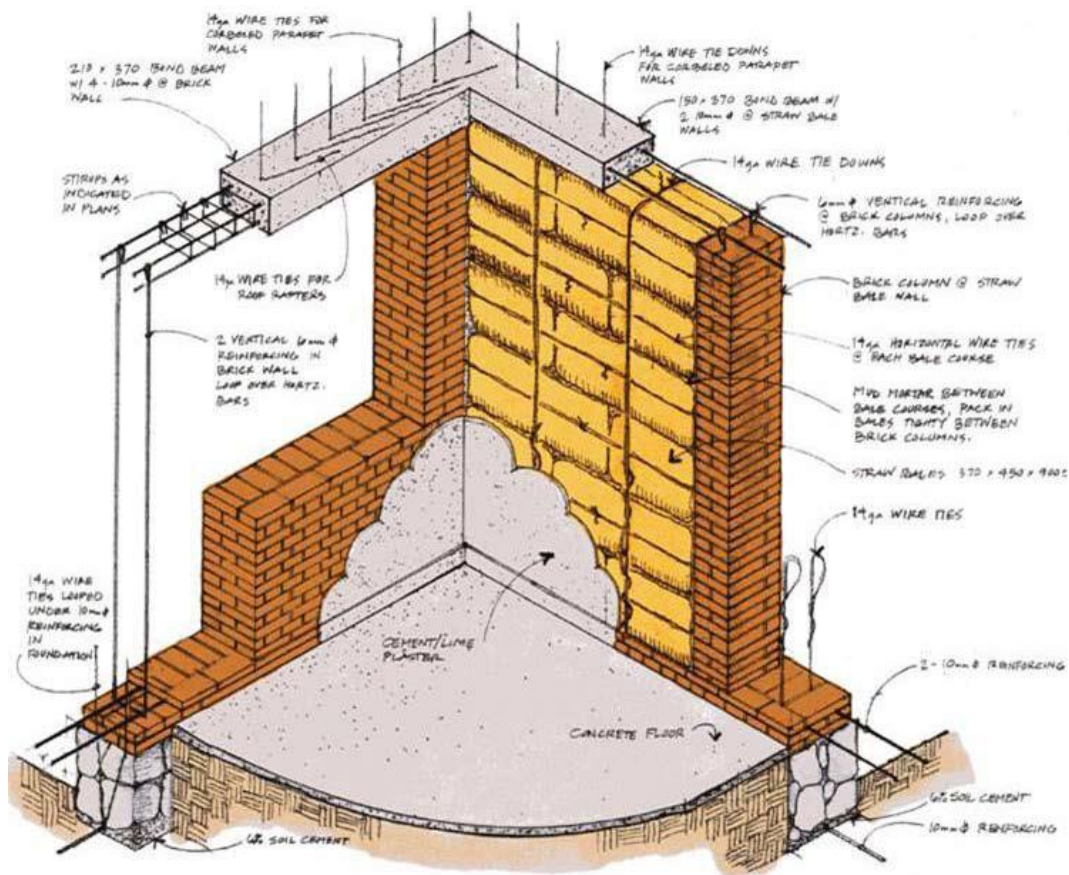


Figure 60 (Tipping Mar + associates, 2005)

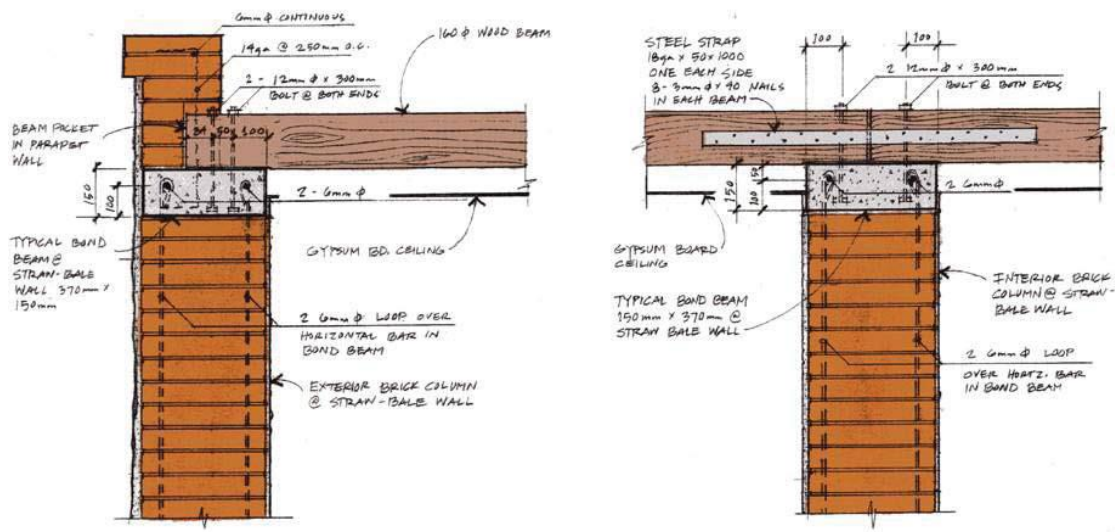


Figure 63 Section (Tipping Mar + associates, 2005)

Although the finished houses are 68 percent more energy efficient than the standard brick construction (in terms of thermal bridging and material use), this construction system is less than ideal. A load-bearing straw bale system would provide better insulation and less embodied energy. But load-bearing straw bale has other drawbacks. Load-bearing straw bale walls don't provide enough support for heavy tile roofs when combined with large south windows (for passive solar heating). Local windows are designed for installation in brick walls. The wood required for rough bucks in a load-bearing wall is expensive, and the carpentry tools and skills are rare. The rainy season coincides perfectly with the building season, and the tarps needed to protect load-bearing walls through a heavy rain are expensive and of low quality. (Lerner, 2004)

The houses built under the program have so far withstood all earthquakes since construction without damage. This is due to the relatively lightweight straw bale walls which resist earthquake loads and absorb seismic energy through deformation. Some brick is retained in the design, mainly to convince homeowners of the strength of the construction. Overall there is a reduction by two-thirds in the number of bricks used compared to a normal brick construction.

Layout and style

The project could not be completed without the support of the local people. Kelly Lerner solicited the input of residents to develop the look of the houses. Homeowners worked with the designer to modify the basic designs by moving doors, windows and interior partition walls to meet their individual needs.

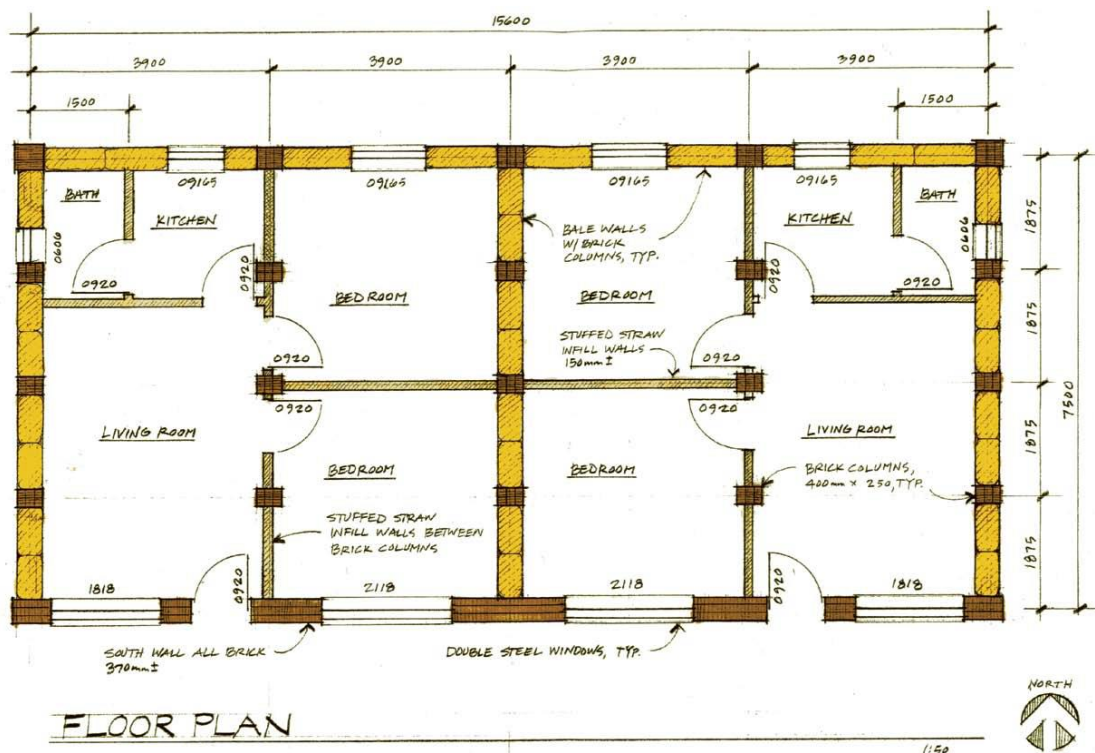


Figure 64 Floor Plan (Tipping Mar + associates, 2005)

It is important that the houses are culturally and aesthetically pleasing in order for the new technology is to be accepted. The designs were adapted to be in keeping with the local style at each village. Villagers watch their urban peers on TV and long for hot and cold running water, indoor bathing and toilets, tile floors, big windows, a roof that doesn't leak or need repair every year, walls that wouldn't melt slightly at each rain. The new house will be substantial and durable brick, with straight flat walls, a white glazed tile exterior, a red tile roof, blue-tinted windows, running water and electricity — just like the village leader's house down the lane. In order to fulfill the dream, they designed a brick post and beam, straw bale infill house which can look identical to the highly esteemed brick house and cost just about the same. A little financial incentive even persuades them it's a good investment of their whole life savings for their family's future. It also uses less fuel for heating and be more comfortable in the winter. But energy efficiency wouldn't matter much if the straw bale house didn't look right aesthetically (straight walls and right angles). (Lerner, 2004)

A post-occupancy survey of 159 families has shown 90 per cent satisfaction with layout and design.



Figure 65 the completed straw bale house (BSHF, 2015)
The large south windows is for passive solar heating.



Figure 66 the completed straw bale house (Tipping Mar + associates, 2005)

This is design at its most elemental, as it was intended: to use creativity and intuition in order to build homes and improve lives. Tipping Mar emerged from the experience inspired by Kelly Lerner's energy and vision. (Tipping Mar + associates, 2005)

Innovative Aspects

- Use of a locally available waste product (straw) to create a building material not used in this part of China before.
- Involvement of a wide range of stakeholders, including local residents.
- Empowerment and skills development of local people.
- Use of insulation in the floor and ceiling.
- Use of passive solar design.

Environmental Sustainability

The use of straw bales has resulted in a two-thirds reduction in the number of bricks used in construction. Large amounts of energy are used to make the bricks, unlike the straw bales. Monitoring surveys have shown that on cold days 5kg less of coal is burned in a straw bale house than a brick house. The straw-bale houses are 68 percent more energy efficient than similar size brick houses. CO2 emissions are reduced by 0.6 - 1.2 tons per year per house (depending on house size and severity of the winter).

There is an increase in soil conservation and drop in use of the firing fuel through a reduction in the number of bricks used for construction. Walls built from straw bales offer tremendous insulation value, thereby reducing fuel costs, CO2 emissions and air pollution and they have very low embodied energy. Straw-bale walls have a CRSI value of 5.8 compared to 0.33 for walls made from solid brick.

There are very high rates of lung cancer and respiratory disease amongst the population in northeastern China, due in part to the extremely high levels of air pollution caused by the burning of highly sulfurous coal for household use. 40-50 percent less coal needs to be burned to keep the straw-bale houses heated. And Health and indoor air quality have improved. This is especially important for the young and old. Homeowners report that there is stable, more even warmth in their homes and they have fewer respiratory ailments.

Financial Sustainability

Construction costs range from \$2,000 - \$3,500 USD for a 50 - 80 m² house with the higher income families choosing to have more expensive designs. The price range per m² is \$36 - \$44 USD. House size depends on the needs and wishes of the owner and the local custom. The total project cost in the period 1999 - 2004 is \$1.7 million USD, i.e. \$2,820 USD per house. ADRA provides the funding for training, technical support and a subsidy per house. The local

government pays an average of \$725 USD per house either in cash, in kind (e.g. building materials) or in labor from contractors at a special negotiated rate.

The project is funded by a combination of external funding matched with internal funding from local government housing departments and a contribution from the homeowners. The external funders use a progressively diminishing subsidy system. In the first year direct subsidies equal approximately 40 percent of the house construction cost to encourage the first families to invest in the new technology. In subsequent years, subsidies diminish to approximately 20 per cent of the house construction cost as confidence in straw-bale technology grows.

ADRA funding has now come to an end and an extension or alternative sources are currently being arranged. There is evidence that the technology is beginning to be used without the ADRA subsidy in those villages where the project is longest established.

The project is designed to be self-supporting using Clean Development Mechanism funding defined under the Kyoto Protocol. Funding under this mechanism would be \$540 - \$1,080 per house (comparable to existing ADRA subsidy levels) and the project is well placed to receive it given that it has fully documented carbon savings.

The houses are simple enough to be built by local construction teams without continuing external inputs. Fuel costs are significantly lower than in brick houses, thus reducing households' expenditure. Many of the local government parties offer low rate financing for the owner's part of the construction cost and this is typically taken up by the poorest households in the program. Owning good quality homes for the first time in their lives has increased the wealth and sense of well-being of the households

Social Sustainability

a. Marketing

To date the project has trained 464 people and built 603 houses in 59 villages in five provinces of north-eastern China. In 2004 an additional two schools were completed, together with associated dormitories. The direct beneficiaries of these developments have been farming families. These include the low-income as well as the middle-income groups. Those on middle income are included to avoid the stigma of the straw- bale housing being seen as being appropriate for low-income groups only.

From the perspective of marketing, if the goal is to introduce a building technique for houses, then it pays to choose the target market wisely. So they've focused the straw bale housing efforts on the rural middle-income group who were already saving money to build a house on their own. As some participants are relatively well off and some are quite poor, some of the finished houses are quite nice and some are just so-so. If the materials themselves are affordable and the construction technique itself is kept simple and clear, individuals will see the potential, and the technique will filter down. The middle-income group who are the potential builders and owners

see a wide spectrum of what's possible with straw bale. Every part of society looks up to the one above it. The popularization in the middle class would influence the poor. (Lerner, 2004)

b. Involvement of local community

Involvement of the local communities is a key element of the project. The project only works in communities that have serious housing needs and have expressed interest in the project. Interested communities are invited to visit an existing project village to talk to straw-bale homeowners and members of the local project management office. In order to participate in the project there must be a local political commitment to provide matching funds, to establish and support a local project management office and to manage the project with complete transparency.

Local community members are involved in areas of house design, materials acquisition and village education. The acceptance of the local community is recognized as essential for the long-term benefit of the project and it is important that the technology is not seen to belong to any one income group. One World Design and ADRA China only work where there are interest and support from the local community leadership.

c. Training

The China office of the Adventist Development and Relief Agency (ADRA) and One World Design Architecture (OWD) provides the training for local construction teams who work with the technical trainers to make sure the homes meet basic quality standards.

To make the training effective, the teacher always communicated with local builders. The teachers do have lots of experience with straw bale construction, while the "students" have all the information about local building materials and systems. So they taught each other. By the end of a weeklong training, the local team (made up of a project manager and builders) will have designed their very own straw bale building, adapted to their local circumstances. If a picture is worth a thousand words, hands-on training must equal a whole library. Although the classroom presentations only required one person, several skilled builders were empowered to review the assignments each day. When there was an in-process construction site adjacent to the training site, the class was formatted with a half-day hands-on, and a half-day in the classroom. (Lerner, 2004)

Technical training has empowered local designers, builders and construction foremen by giving them new design and construction skills. Members of the local Project Management Office have gained extensive management experience and new homeowners have learned how to take care of their homes and have a greater understanding of the natural environment. Participants in training programs are now forming a Straw Building Association as a way of keeping abreast of international research and acting as a support group for each other.



Figure 67 (Tipping Mar + associates, 2005)



Figure 68 the straw bale house being built (BSHF, 2015)

Local technical teams were trained to build and maintain the houses.



Figure 69 the straw bale house being built (BSHF, 2015)

d. Barriers

- A Cultural preference for brick built houses was overcome by the incorporation of brick into the building system and a long-term commitment to education, financial incentives and on-going technical support.
- Aesthetic preferences of residents occasionally conflicted with the energy efficient or passive solar design. In these cases, the resident and designer would work together to find a compromise.
- Lack of an established chain of manufacture and supply for straw bales in local areas meant that assistance had to be provided with setting up local straw bale production or coordinating the sharing of balers or providing interest-free loans to purchase balers when required.
- Clear, concise and strongly enforceable contracts were required to address the problem of government corruption in some areas. These contracts laid out the duties of each party and the requirements of transparency. The shared financial contributions also helped to ensure cooperation and a commitment to working through problems.

- The limited availability of cost-effective baling machinery in the area was addressed through improvements being made to the machinery of two local baler manufacturers.
- Lack of official standards and codes for larger public buildings such as schools and clinics.
- There was evidence of cracking in the render where brick and straw interface, which was overcome by using a wire meshing reinforcing and training the construction teams in proper plaster mixtures and application.

e. Lessons Learned

- For real environmental impact and long-term sustainable development there needs to be a large-scale transfer of the technology.
- Local community interest, enthusiasm and commitment are essential elements to the success of the project. It is a waste of time and resources to train a community in which the project will not be supported.
- The involvement of all stakeholders helps to maintain motivation to successfully complete the project and keeps costs down.
- It is important to build to the best possible quality that the local materials, local skills and budget allow ensuring the highest possible standards.
- Building construction systems should be allowed to develop organically over time in relation to the local climate, building skills and materials.
- Straw-bale technology should be developed by studying and adapting existing local technologies.
- Adequate time must be given to the early phases of research, training, cooperative design and planning.
- Good technical training should be integrated with local design and local building skills.

Evaluation

- Post-occupancy surveys carried out by ADRA in each village show high levels of satisfaction with the houses although there is limited understanding of the wider environmental benefits that are being achieved.
- Surveys have also been carried out on levels of coal consumption. These show that on cold days 5kg less of coal is burned in a straw-bale house than a brick house.

- Surveys on energy efficiency show that they are 68 percent more efficient than similar size brick houses.

Transfer

The project originally started with 21 houses in 1999 and has now spread to 59 villages and has 603 houses, due to the demand from local people. It covers five provinces of northeastern China where there are large straw surpluses.

There is evidence of transfer of straw-bale construction outside the scope of the project as five duplexes totaling 504m² were built using straw bales in 2004 in Tangyan County, these were independent projects not funded by ADRA. More straw-bale constructions are planned in Tangyan.

Professor Kuang at Jiangxi University is carrying out a research program into the use of straw-bale technology in southern and central china and will be building demonstration straw bale houses on the university campus.

Local building codes have been modified to include provision for straw-bale construction in some local governments. Other NGOs in China have adopted the straw bale technology and it is also being used in the Huangbaiyu Ecologically Sustainable Model Village in Benxi Liaoning. A range of other NGOs including World Vision, UNDP and ADRA have similar projects in Mongolia, Mexico, Iraq, Belarus and Argentina. (BSHF, 2015)

The development of straw bale housing in northern China

To date the straw bale housing has spread in 5 provinces of northern China. In 2009 the Heilongjiang (one of three-province in north-eastern China) Provincial Construction Department published 'Guidance on the reform of rural mud, stone and rubble house', which defined the urge policy and standard for rural energy efficient housing. Every level of the Heilongjiang Provincial Construction Department has begun to promote straw bale housing, passive solar design and other energy efficient building techniques, materials and products. And the government provided subsidy for constructing energy efficient housing and establishing a relevant chain of manufacture and supply for energy-efficient building materials and products. There were 177,600 new energy efficient houses in the province in 2009, its proportion in all the new houses was 80%. The reform of mud, stone and rubble house reached the energy saving standard totally. So far the straw bale housing are popularized in Heilongjiang Province. (Shang, 2016)

6.3 ADRA Straw Bale Housing Becomes an Eco-Friendly Solution for Post-Earthquake China

SILVER SPRING, Md. ---On June 1, the Adventist Development and Relief Agency (ADRA) launched

a new project to introduce straw bale housing construction technology to assist families living in China's earthquake-affected Sichuan Province.

"This technology has many benefits," said Sarah Ng, public relations officer for ADRA China. "It can make an impact in helping China reduce carbon dioxide emissions. Since the materials utilized originate from farming waste, straw bale technology reduces the amount of coal needed in the winter by 68 percent. It also creates buildings that are both fire and quake-resistant." (McGill, 2009)

The project will build two model straw bale homes in two villages in Sichuan Province.

"We hope that after these two houses are completed people will see and feel the benefits of this method of construction, and start building them in Sichuan," said Ng.

In June, Lerner, a leading eco-architect in the U.S., traveled to Sichuan to assist ADRA China in developing new designs suitable for the more humid conditions of the Sichuan Basin.

This project is in response to a rising need for housing following the 8.0-magnitude earthquake that struck the region on May 12, 2008, leaving nearly 88,000 either dead or missing, and nearly 400,000 injured, according the United Nations Children's Fund. An estimated 5.5 million homes collapsed in the disaster and another 5.9 million were severely damaged, the Sichuan Provincial Government reported to the World Bank. (McGill, 2009)

The home of Wang Jiajun family in Luhua Village Zhongjiang County Dejiang City and the home of Li Xuemei family in Xigao County were the pilot projects of the straw bale housing. The American architect Kelly Lerner designed the homes. The professor Kuang Qingmei from Jiangxi Engineering Institute was the technical guidance in the building process and was in charge of social marketing among homeowners. ARDA CHINA provided the construction equipment such as straw baling machine, technical assistance, the training of builders and partial funding. The homeowners and other villagers were builders.

The home of wang Jiajun is a blend of lightweight steel frame and straw bale infill walls. The floor area is over 200M². The construction cost is about 180,000. The price per square is about 900 yuan.

The home of Li Meixue is a blend of reinforced concrete frame and straw bale infill walls. The floor area is 170m². The construction cost is about 100,000 yuan. The price per square is about 600 yuan.

ADRA straw bale housing was not expanded successfully. Only three homes were built. It is because there were more barriers to the promotion in Sichuan than in north-eastern China. (Huang, 2011)

Firstly, the climate of Sichuan Basin is often damp, rainy, cloudy and foggy. It is warm in the winter, hot and rainy in the summer. The average temperature in January is 5-8 degrees. The average temperature in July is 25-29 degrees. The rainy season extends from May through September. The rainiest month is July, the average rainfall is over 200mm. There are 250 to 300 cloudy and rainy days a year in the plain. The climate in Sichuan is much warmer and wetter than north-eastern China. Thus, the thermal insulation performance of straw bale housing in winter is not that needed. And the architect didn't have enough experience of designing a straw bale house in such a wet and humid zone. There was not any modern performance based building code for such wet and humid climate worldwide either. She couldn't ensure the durability performance. Straw bales are an extremely moisture-sensitive wall material. If they get soaked the tightly bound hollow straw fibers are capable of absorbing and holding a great amount of water. Before they can dry out they can remain wet for long enough for fungal decay to start if in a temperate climate with high humidity. Plasters leak and water repellent treatments fail. A straw bale building must be designed and constructed in such a manner that the straw always remains dry throughout the entire building process and the lifetime of the building. However, the cement/lime plaster of the straw bale houses started breaking up soon after the projects were finished, due to the changing of the air humidity.

Secondly, the agricultural mechanization of north-eastern China is much more advanced and widespread than that of Sichuan. For example, in one of the three provinces in north-eastern China, the Jilin Province, the mechanization proportion for seeding, plowing and harvesting are 86.6%, 92.3% and 50.2%, the integrated mechanization proportion is 80% (the People Net, 2015). The high agricultural mechanization level made possible the manufacture of bales or blocks out of straw in north-eastern China. This is the reason that the price per m² of straw bale housing in north-eastern China is lower than in Sichuan. It also benefits to the promotion of the straw bale housing in north-eastern China. However, in Sichuan the integrated mechanization proportion is only 29.37%, is not reach half of the national average. (Sichuan Provincial Bureau of Statistics, 2009) The conditions in many villages were not available for the manufacture of straw bale.

Thirdly, there was a cultural barrier. Although the straw and other plant fibers have been used in parts of buildings for centuries in Sichuan. Generally their use was non-structural and often required frequent replacing. So most villagers thought that straw was a building material for the poor people only and the straw bale house was not stable.

Fourthly, there was an economic barrier. The farmers' average income in Sichuan is less than the national average. However, in the pilot project of Wang Jiajun's home, the lightweight steel frame was used. The level of the domestic lightweight steel framing industry was quite low, leading to the high price. The construction cost was not affordable for most villagers.

Fifthly, the work of ADRA didn't gain support from most of the homeowners and the local government. Because there were a cultural barrier, economic obstacle and the mistakes and missteps in the pilot projects, the homebuilders did not want to take the risk of using a new

technology. And there was not any political commitment and subsidy from the government. After the pilot projects were completed, the project money stopped flowing. Everything returned to the way it had been. The homebuilders aren't using the natural building technique that they learned.

The pilot projects did play a fundamental role in introducing sustainable building technologies. The local builders, experts, craftsmen and architects had opportunities for learning and training building techniques and building relationships. They are the real local examples, testing grounds for new techniques and materials and real-life laboratories for monitoring and feedback. And there are real physical and financial benefits to the people using the building. But One building by itself, or several buildings, or even hundreds of buildings will have little impact on long-term sustainability or improve the living standard for more than a few.

For real environmental impact and long-term sustainable development, technology transfer must be the goal. That means there will be real and measurable changes in the knowledge, attitudes, and practices of the local community long after the project is completed. Like any other worthwhile project, technology transfer is a slow evolutionary process that requires long-term commitment and funding and an ongoing relationship. Like learning a new language, there are missteps and course corrections along the way. A single building is one good tool in technology transfer, but it is not the primary goal. But when the pilot project was finished, they did not have the good fortune of a long-term funding focused on technology transfer. (Lerner, 2004)

The pilot buildings should reach the highest possible standard in the allowable local skills and budget to attract money, political commitment and homebuilders' interest. But if they fail to attract interest, the initiators (architects and NGOs) have no choice to leave them and go elsewhere. Because it is a waste of time and resources to train a community in which the project will not be supported.

6.4 Conclusions

ADRA China and OWD have implemented its straw bale housing program in North-eastern China and Sichuan. It is expanding in north-eastern China, but stopped at the pilot projects in Sichuan. The process gives some guide to the development of the rural straw bale housing:

The ultimate goal of rural reconstruction is technology transfer, which needs a long-term funding, local grassroots' support and political commitment.

The early phases of research, training, cooperative design, and planning are important, which can make or break a project. And the pilot projects should be as good as possible to attract money and people's interest.

It is important that the houses are culturally and aesthetically pleasing in order for the new technology is to be accepted. Homeowners and the designer should work together to modify the basic designs by moving doors, windows and interior partition walls to meet their individual needs. Homeowners' aesthetic preferences occasionally conflicted with the energy efficient or passive solar design. In these cases, they would find a compromise balancing actual, real life conditions with design ideas. Natural building won't go forward if it's yoked to a particular style. Only if buildings are actually getting built can we get feedback and keep working to better them.

The technical training should be combined with local design. The teacher should communicate with the students - local building professionals and learn from each other. Although the teachers have a lot of experience with straw bale building, the students know all about local building materials and design systems, it is important that the teachers and students work together to adapt the straw bale housing to the local climate and local materials or skills, because the ideal design without the practical consideration of local implementation won't go forward. Developing a solution in partnership with local expertise is the most efficient and effective path to successful technology transfer. The ultimate goal of the training is to develop local experts who can take the work forward on their own.

Building for the very poor may not be the best entry point for technology transfer. In fact building primarily for the poor may relegate the sustainable building technology to the category of poverty housing and make it less appealing to the general population. Select middle-income people who are already saving money to build a house on their own as the target populations. Expand awareness about its benefits and make its process or products as appealing as possible, then people will see its potential, and ultimately creating consumer demand. Then the technology transfer will be popularized in the middle-income group, and expanding to the poor group, because every part of society looks up to the one above it. Part of technology transfer is marketing.

Select place which is relatively adequate for the development of straw bale housing. Straw bale is an extremely moisture-sensitive wall material. A straw bale building must be designed and constructed in such a manner that the straw always remains dry throughout the entire building process and the lifetime of the building. It is technically easier in the dry climatic zones than wet climatic zones. So we could develop it in the dry climatic zones first, making it popularizing, and then it would spread into other climatic zones. The high proportion of mechanized farming makes the straw baling manufacture possible, which benefits to the expanding. Likewise, we could develop it in the place has high agricultural mechanization level first.

7 Ren Weizhong's self-building eco-houses in Anji

Ren Weizhong was an ordinary worker living in rural Anji County. He has been environment conscious since the 1980s.

Anji is a small county in Zhejiang Province. In the 1990s, Rural Reform had developed over ten years in China, the rural economy had been improved, and many farmers in Anji had already had financial ability to improve their living environment. They demolished their homes and reconstructed brand new ones, which became a prevailing social phenomenon. Some villagers even borrowed money to rebuild homes with expensive materials just to keep up with the Joneses. They have borne a big financial burden since then. At the same time, the large amount of construction waste polluted the environment. Furthermore, due to lack of environmental awareness, the new homes were not energy efficient. In Ren Wei-zhong's opinion, the appearance design of the new homes was a lack of aesthetic feeling, which was also visual pollution.

He became caught up with the idea of transforming his hometown into an eco-town. He has been working to establish an eco-friendly community model that can be followed as a standard. It must strike a balance between human development and a healthy eco-system. He thought that building an eco-village would be the best start for creating such sustainable communities.

He actively promoted environmental awareness among his townsmen, and paid out of his own pocket to build demonstration eco-homes in communities. His green initiatives were also recognized by the local government and massive projects were launched in Anji to become an eco-town.

Ren Weizhong's first attempt, an eco-home built with recycled materials, was also met with caution and questions. A group of experts was invited to assess the sustainability of my eco-home; and no one was sure about my design and the construction materials. One of them even predicted that that house would collapse within ten years. But the negative feedback didn't stop Ren from pursuing his green dreams. He turned to the ancient wisdom of building for inspiration and invited traditional, experienced carpenters and bricklayers for advice and suggestions. With their help, his first eco-home was built, and still stands today, as well, gained popularity nationwide.

Afterwards Ren Weizhong built four more demonstration eco-homes. In his eco-homes, those modern requirements can be found along with traditional Chinese architectural elements. (Wang and Ren, 2015) These eco-homes are not for living by himself, but experimental projects for promoting natural sustainable construction. Ren Weizhong attempted to establish a rural housing model which is low-cost, environmentally friendly, harmony with the traditional rural landscape,

comfortable, adaptive to the environment throughout China and innovative in vernacular building materials and construction methods. Based on these requirements he constructed the five eco-homes. Each one has its own unique feature. (zhang, 2015)

In the 1990s, China's rural reform has been carried out for more than 10 years, some farmers have a certain economic capacity to improve their homes, demolish old houses to build new houses become so prevalent in rural areas as a social phenomenon. Regardless of their economic condition, building house has become a major event in the lives of farmers, which makes most farmers bear a heavy financial burden, and even become a farmer's obsession. But the problem is far more than that. Ren Weizhong was an ordinary worker in Anji Shipping and ports authority. Live in a rural area, he began to focus on environmental protection from 1990, he wasn't satisfied with the house built in rural place, even felt pain. The pain is the pollution made by construction, the pollution is not only spiritual – the house is very ugly, but also the materially – the environmental pollution caused by exploitation of mines and the manufacturing of building materials. Ren Weizhong gradually began to think about build house by himself, these houses is not for himself to live, but they are a declaration to the community. The ideal rural house of Ren Weizhong is not only cheap and appropriate but also creative. After thinking, he decided to build these house with the local materials. The innovation mainly reflects in two area: 1. Improve local material, 2. The innovation of construction method. From 2005, he has built five houses. The construction method and function of these houses are different. He wants to create a rural construction system to cope with the economy, resources, the environment of various regions. The houses have two kinds of structure, the one is rammed earth walls and timber framework, the other is load-bearing rammed earth walls. The former structure is earthquake-resistant. The latter can be applied to regions lack of timber and happen less earthquake.

There is a long history of rammed earth housing in Anji County. Most of the old rural houses in Anji are a blend of timber frame and rammed earth infills. With the diffusion of modern building materials, traditional rammed earth construction faded. The rural residents demolished their old houses and rebuild them with modern building materials. Ren Weizhong bought the demolished wood frames from the villagers and reused them in his experimental houses. The rest of wood used in the houses is fast-growing Chinese fir. He also brought back rammed-earth techniques in his eco-houses practice.



Figure 70 Ren's four experimental houses (Ren, 2013)

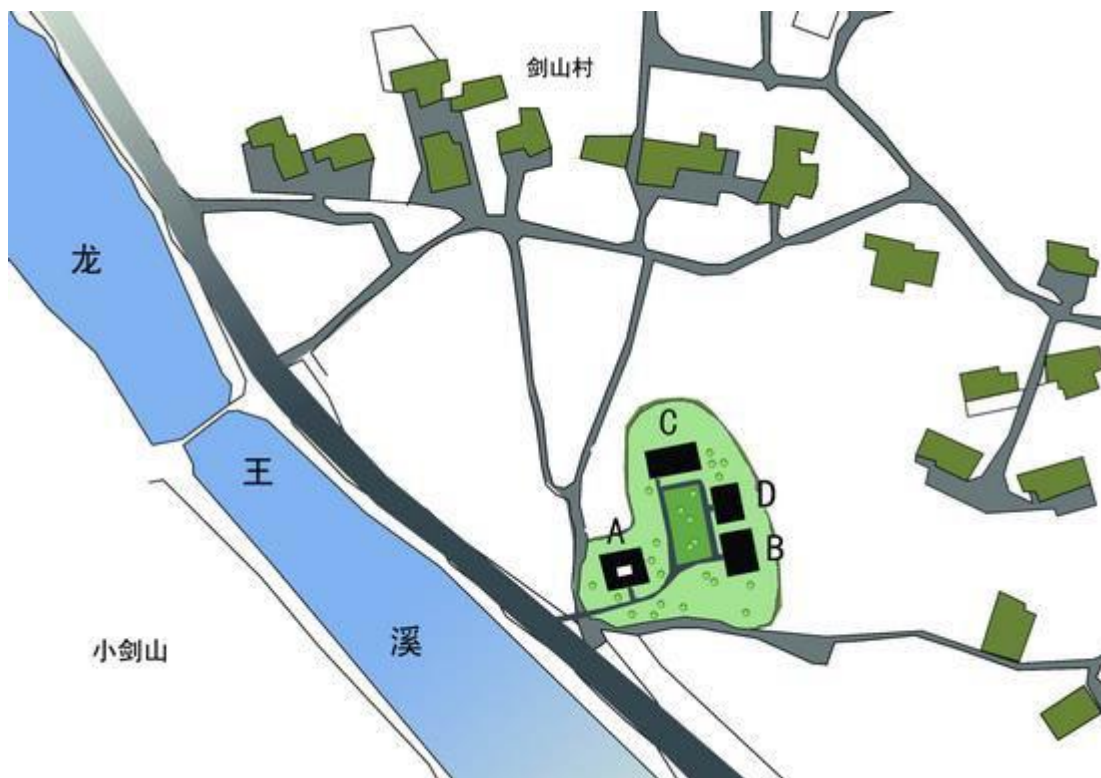


Figure 71 the masterplan (CAMA, 2008)

The four houses are located in Jianshan Village, Anji County

7.1 House 1, Renovation of Traditional Courtyard Residence

Gross building area: 170 m².

building cost: RMB 75,000;

Date of construction: June-October, 2005



Figure 72 Eco-home 1 (CAMA, 2008)

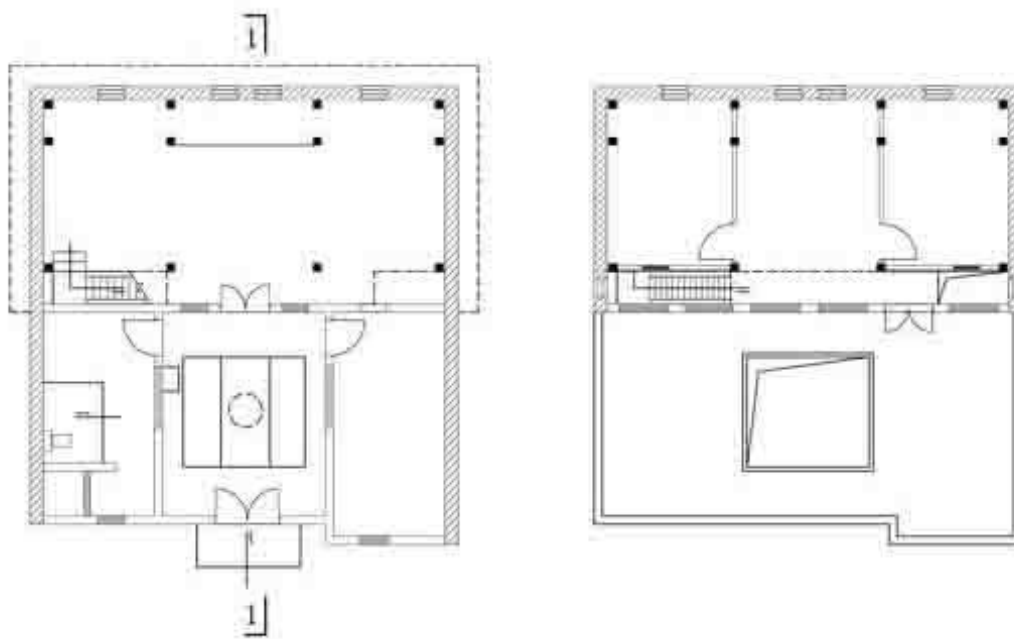


Figure 73 Ground floor plan and second-floor plan (CAMA, 2008)



Figure 74 1-1 section (CAMA, 2008)

Eco-home 1 is designed for a family of three. The layout of the home is an innovation based on Anji's traditional courtyard residence.

Compare to the traditional courtyard residence, the main room is no longer partitioned. It becomes an open space for dining and living. Skylights are added to improve the lighting of the main room.



Figure 75 Main room (CAMA, 2008)



Figure 76 Patio (CAMA, 2008)



Figure 77 Patio after rain (Source: <http://taizhou.19lou.com/forum-2012-thread-142151456380909104-1-1.html>)

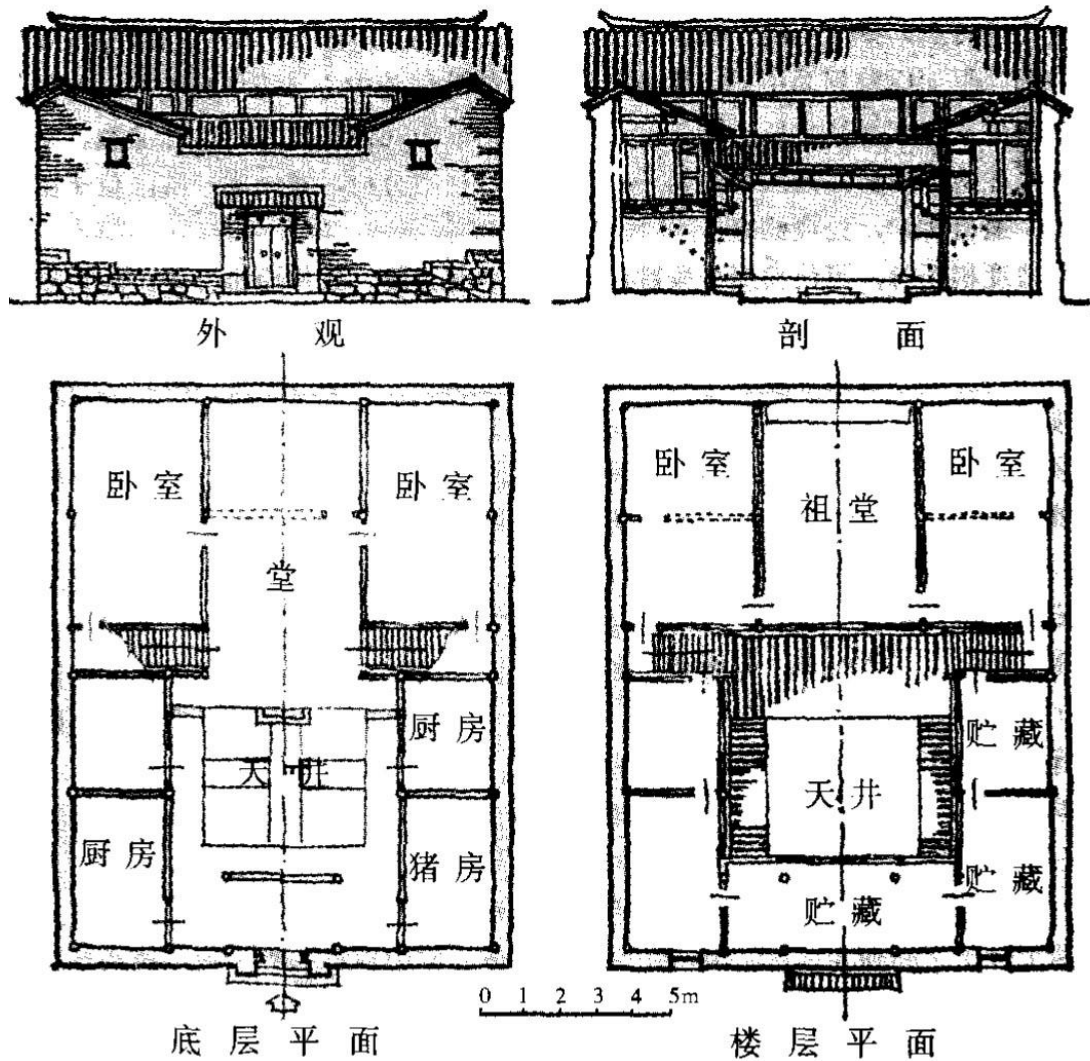


Figure 78 'A Signet' (Yikeyin, 一颗印) - a typical traditional courtyard Residence in Southern China (source: <http://home.tinp.net.tw/mypage/00125728/w-6.html>)

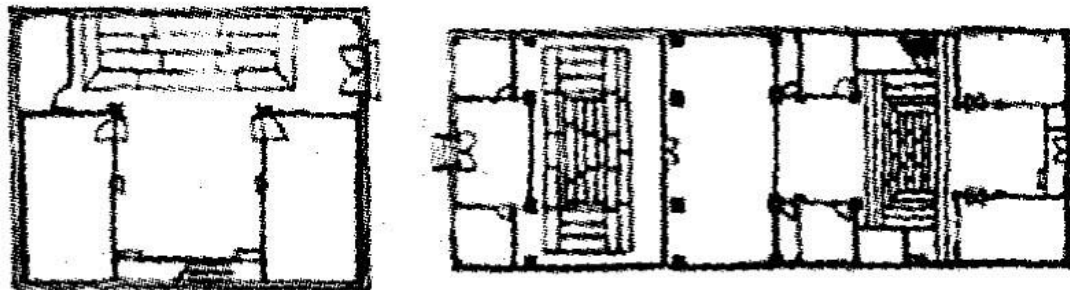


Figure 79 typical floor plan of traditional residence in Huizhou, Southern China (source: <http://home.tinp.net.tw/mypage/00125728/w-6.html>)



Figure 80 an apart of the painting 'Along the River during the Qingming Festival' (Source: <https://i.ytimg.com/vi/vjUevEG3JnU/maxresdefault.jpg>)

In the traditional courtyard residence in southern China, the courtyard has the function of collecting rainwater, fire protection, lighting and ventilation. The residences always have two floors, the courtyard in Southern China is smaller than that of residence in northern China, for protecting from baking under the summer sun. As shown in the painting 'Along the River during the Qingming Festival', there are always designs of bridge, pathway, water and plants in the courtyard, forming a beautiful interior landscape. When in the rainy season, people would like to listen to different sounds of raining on the stone, leaves and wood in the courtyard, which is a nonchalant happiness. There is a line of a poetry by Li Shangyin (李商隐) expressing the happiness definitely, 'leaving the withered lotus leaves to listen to the rain' (留得残荷听雨声).

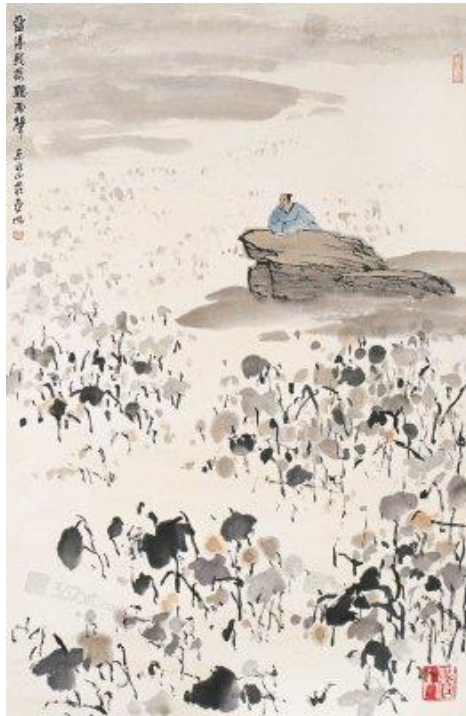


Figure 81 'Listening to the Rain on the Wilted Lotus Leaves Sounds' – 残荷听雨 (can he ting yu) (Source: http://367art.net/uploads/artGallery/c110406/1302025c309150-35540_lit.jpg)

The most important function of the courtyard is remaining rain water, we called it '四水归堂' in Chinese, because water means wealth in Fengshui. There is also a more profound reason. When we are in mothers' wombs, we are in the water (amniotic fluid), so the sound of water can comfort us. In the ancient China, the lecture hall for the emperor, 'Mingtangpiyong' (明堂辟雍), is surrounded by a round pool of water, which represents the womb and amniotic fluid.

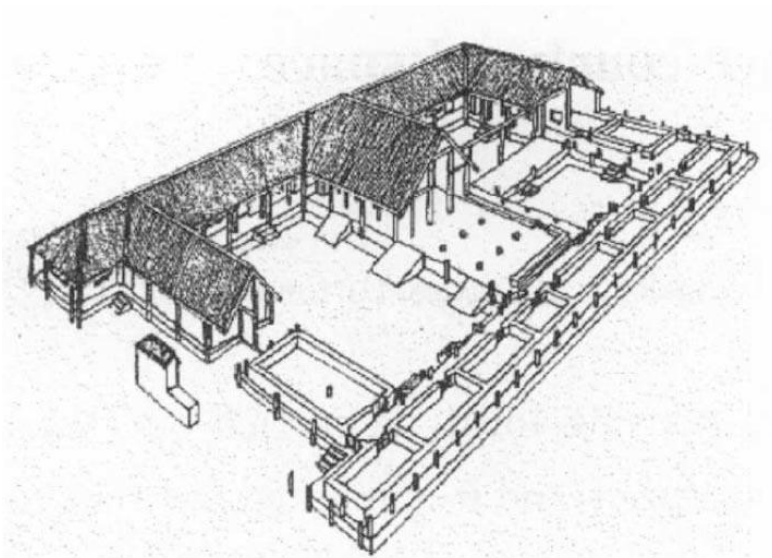
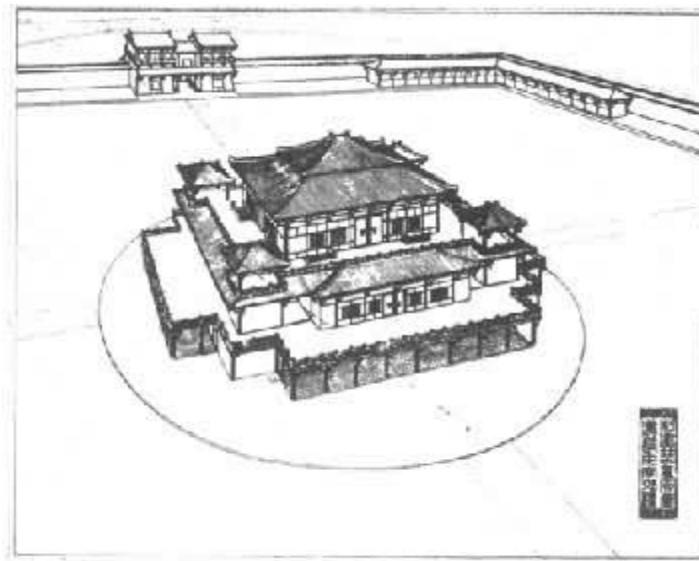


Figure 82 Ruins of residence in northern China, built in Xizhou period (source: <http://home.tinp.net.tw/mypage/00125728/w-6.html>)



汉长安南郊明堂辟雍复原图

Figure 83 The lecture hall of emperor - "Mingtangpiyong" (明堂辟雍) (source: http://www.chinabaike.com/article/1/78/181/2007/20070510111426_2.html)



Figure 84 The front wall (source: <http://taizhou.19lou.com/forum-2012-thread-142151456380909104-1-1.html>)

The front wall is always very simple and modest, however, the interior is a totally different world. The scenery in the courtyard represents the world inside the homeowner, which is a gray space linking outside and inside, open but quiet. That is the aesthetics of traditional courtyard house, to be implicative and peaceful.



Figure 85 sunny corridor on the second floor (Ren, n.d.)

The openings of rammed earth wall can't be too large. a) The width of a window should not be more than 1.2 m and not more than $\frac{1}{3}$ of the length of the wall. b) The length of walls between openings must be at least $\frac{1}{3}$ of their height and not less than 1 m. (Minke, 2006)

To improve the lighting of the second floor, Ren designed a sunny corridor (Figure 85) with skylight. Heat from sunlight passing through the glass, absorbed and stored by the interior rammed earth wall and the glass prevents the escape of radiant heat of the interior walls. The design optimizes heat gain and minimizes heat loss during cold times, but leads to excess heat gain in hot times. So he covered the skylight of the sunny corridor afterward, as shown in Figure 86.



Figure 86 Living room and bedroom on the second floor (Zhang and Ren, 2016)

The small windows on the back wall help to form cross ventilation.



Figure 87 (left) the flat roof for drying the gains (CAMA, 2008)

Figure 88 (right) the reformed flat roof (Ren, 2013)

The former pitched roofs of the east and west side rooms have also been changed to flat roofs that can be used for drying gains. The patio was open-air. These areas are accessible from the second floor of the rear building.

Afterward, due to the drainage problem in the rainy season, he added a rain shelter over the patio and the flat roof. The part over patio is transparent, as shown in Figure 88.



Figure 89 the water pipes in the flat roof (Ren, 2013)

The flat roofs are made of precast concrete panels with water pipes. There is a circulating water system. The well water comes to the water pipes and going from the tank underground. The cooling technique can avoid the need for air conditioning in the hot humid summer. The indoor

temperature of the east and west side rooms can be kept under 26°C on hot days. And the power consumption of the system is only a tenth of that of the air conditioner.

House 1 is a blend of timber frame and rammed earth infills. The ratio of the sand, clay, and lime is 7: 2: 1. The sand was collected from the river bank nearby. In the five houses, house 1 has the highest proportion of sand in the mixture. The builders mixed it manually. The rammed earth walls were built from June to August in 2005. The length of the walls is up to 11 meters. The height of the walls is up to 5.2 meters. And the height of gables is 6.6 meters. They rammed the walls of the ground floor before built the timber frame. When the timber frame was completed, it was used as a scaffold with bamboo springboard. On the scaffold, they continued to ram the walls of the second floor. The timber frame was helpful to prevent the walls of the second-floor tilt inward in the construction process. There is only one crack located on the split-level place of the lateral wall, as shown in Figure 90. It is about 2 meters long and about 5 mm wide at its widest point. According to the analysis, it is caused by asymmetric settlement of the gravel foundation.



Figure 90 the crack on the lateral wall of house 1 (Zhang and Ren, 2013)

7.2 House 2, Using Traditional Pebble Masonry

Gross building area: 180 m².

Building cost: RMB 65,000;

Date of construction: July-October, 2006



House 2 is a blend of timber frame, pebble masonry and rammed earth construction. The timber frame is recycled from the demolished houses. The exterior walls of the ground floor are pebble masonry. This building can function as a civic center. The first floor is used for science exhibitions relevant to agricultural production. The second floor is used for conference and wedding.

Figure 91 House 2 (Zhang and Ren, 2016)

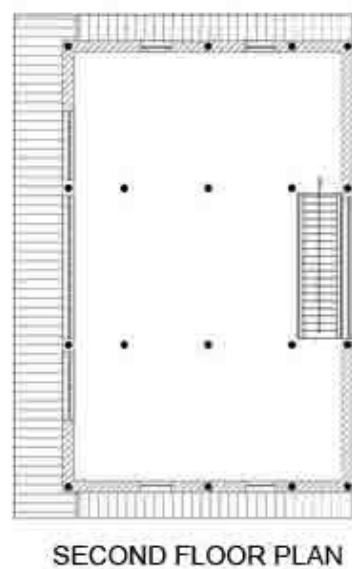
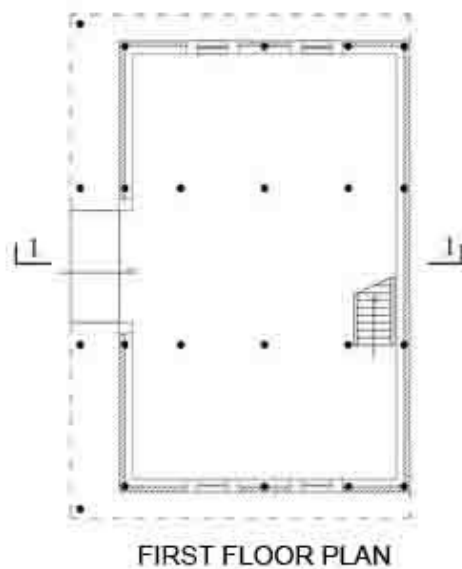
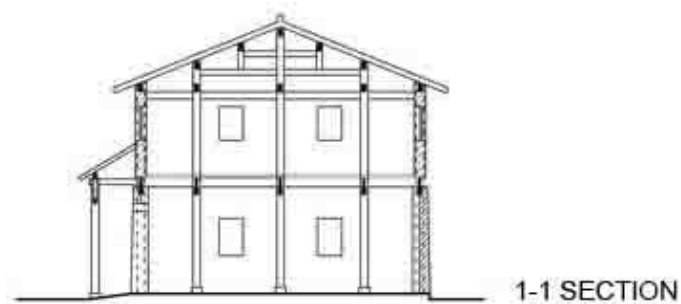


Figure 92 Section and plan of House 2 (CAMA, 2008)



Figure 93 Exhibition hall on the ground floor (Ren, n.d.)



Figure 94 (left) Tea room on the second floor (CAMA, 2008)

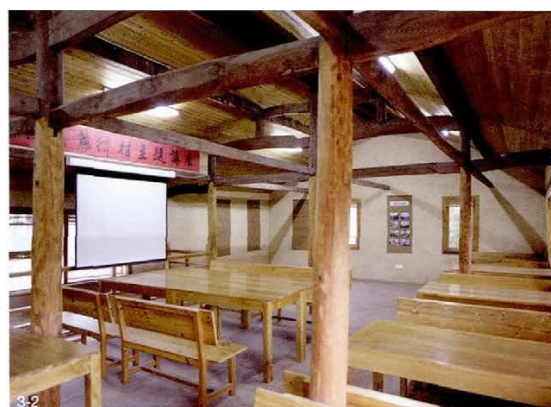


Figure 95 (right) Conference hall on the second floor (Ren, 2013)



Figure 96 People making rice cake and holding wedding in the house (Ren, n.d.)

7.3 House 3, Modernizing the Rammed Earth Construction

Gross building area: 264 m²

Building cost: RMB 85,000 (interior renovation not included)

Date of construction: June-December, 2006

House 3 is a hotel.



Figure 97 house 3 (Ren, n.d.)



Figure 98 Reverse-camber roof (Ren, n.d.)

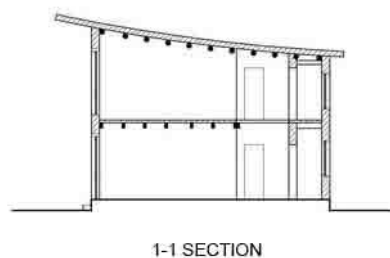
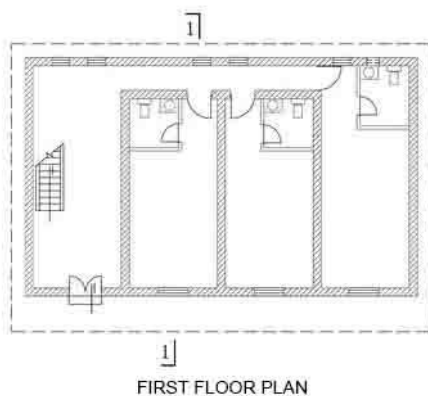


Figure 99 Floor plan and section of House 3 (CAMA, 2008)

House 3 is load-bearing rammed earth construction with ring beam. In areas without sufficient timber supply, rammed earth can be used as an alternative. Lightweight loam are used on the

walls to improve the thermal and acoustic insulation. House 3 have the best thermal insulation performance in the five experimental houses. The rear corridors, French windows and reverse-camber roof gives the house a sense of modernity.



Figure 100 House 3 being built (Zhang and Ren, 2013)



Figure 101 House 3 being built (Zhang and Ren, 2013)

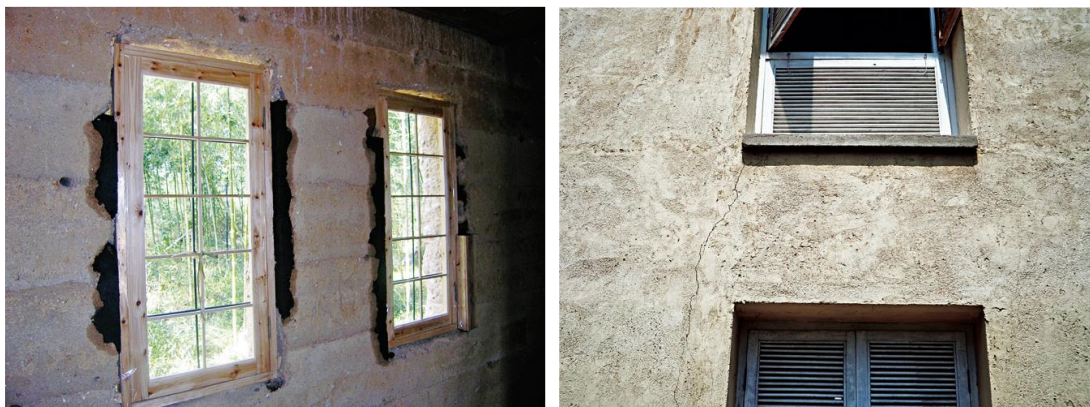


Figure 102 (left) The windows on the back walls in the construction process (Zhang and Ren, 2013)

Figure 103 (right) cracks on the walls of House 3 (Zhang and Ren, 2013)

The space for openings in the ground floor were reserved; the openings of the second floor were excavated from the completed rammed earth walls, as shown in Figure 101 (Zhang and Ren, 2013). For the window with width less than 60 cm, lintel is not needed, the window frames were installed from interior, as shown in Figure 102.

The ratio of sand, clay and stone is 9: 9: 2. It is mixed by machine. The walls were rammed manually. The duration of the project is from June to August in 2006. The length of the walls is up to 16m, the height is 7m. So far there have been some small cracks nearby the openings, as shown in Figure 102 (left) The windows on the back walls in the construction process (Zhang and Ren, 2013) Figure 103.

7.4 House 4, Solving the Problem of Earth Resource

Gross building area: 66 m²

Building cost: RMB 28,000

Date of construction: April-June, 2007



Figure 104 No.4 eco-house (Ren, n.d.)



Figure 105 Basement (Ren, n.d.)

Some people worried that the topsoil consumption of rammed earth construction would destroy farmland. To solve the problem, Ren Weizhong designed the house 4. The solution is digging out a basement and using the excavated earth to build the house. The split bamboo poles are used to decorate the walls. The basement can be used for storing food, crops and seeds and enjoying the cool in the summer.

The width and depth of the house are 11m and 6.6m. The ratio of sand, clay and lime is 4: 5: 1. It was mixed manually. The walls were rammed by two elders manually. So far there have been a 1-cm-width crack in the middle of the back wall. It is caused by the low ramming strength and the high proportion of clay in the mixture. The elders didn't have enough physical power for ramming, which decreased the degree of density of the walls. The high proportion of clay in the mixture made the walls shrink too much during the drying process, which led to the crack.

7.5 House 5, combining contemporary art



Figure 106 House 3 (Zhang and Ren, 2016)

The structure of house 5 is timber frame with rammed earth infills, the same with that of house 2. It is a residence. The timber frame and the earth are recycled from the demolished old houses. It is designed by the Chinese architect Zhang Qin living in France. Ren managed and constructed. The architect provided Ren with the most thorough and up-to-date information possible about rammed earth techniques. And they work together through internet to adapt the solution to local climate and materials. The professional guidance was helpful to the construction process.

The energy efficient roof

In the hot summer and cold winter area of China, the top floor is colder than the lower floor in the winter, and the top floor is hotter than the lower floor in the summer. Anji County is located in this area, during the hot summer, people live in the top floor cannot sleep at night due to the high temperature. Thus, many people move to lower floor in the summer. The early rural houses didn't adopt any thermal insulation technique for the roof. There was only tiles and ceiling. Currently, with the improvement of the rural economy, farmers have financial ability to improve their houses, they add a layer of cast-in-place or precast concrete panel under the pitched roof. The concrete panel and the pitched roof enclose an air space. Heat from the sunlight is absorbed by the tiles, the radiated heat of the tiles is stored by the concrete panels, and conducted slowly inwards through the concrete. The tiles prevent the escape of radiant heat from the storage concrete panel. The heat radiated by the concrete panel is therefore trapped within the air space, further heating the concrete panel surface. Heat will take several hours to reach the interior of the building. This means that the room below remains comfortable through the day and receives slow, even heating for many hours after the sun sets. Such designs optimize heat gain and minimize heat loss during cold times, but lead to excess heat gain in hot times. In the hot days, the temperature of the tiles can be as high as 60 ~ 70 °C.

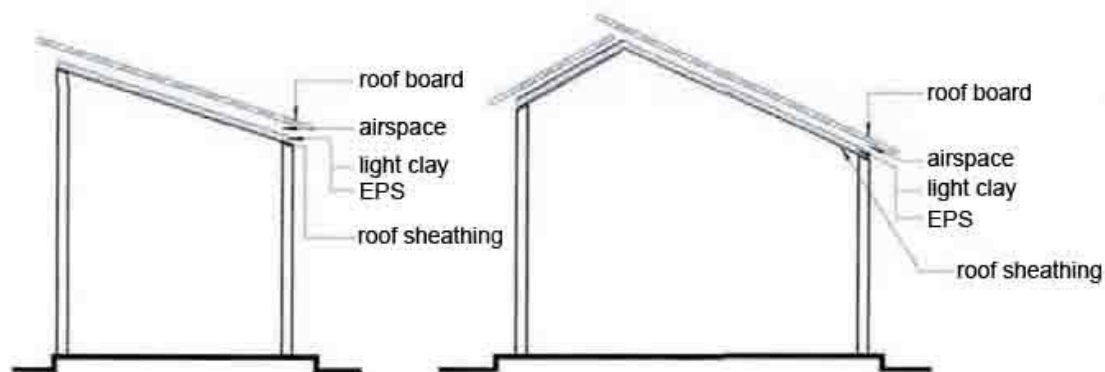


Figure 107 Roof structure designed by Ren Weizhong (Zhang and Ren, 2013)

Ren designed an innovative roof structure for his experimental houses. As shown in picture Figure 107, a layer of 5-cm-thick Expanded Polystyrene (EPS) covers on the roof sheathing, then a layer of 5-cm-thick light clay covers on the EPS, and there is a 7-cm-thick airspace between the light clay and roof board. The airspace has operable vents. The system is used on the single

pitched roof or the south-facing part of the double-pitched roof. The roof board is asphalt shingle. There is ABS roof seal. The system was used in House 2 and House 3.



Figure 108 House 2 (left), House 3 (right). Builders were covering light clay on the roofs. (Zhang and Ren, 2013)

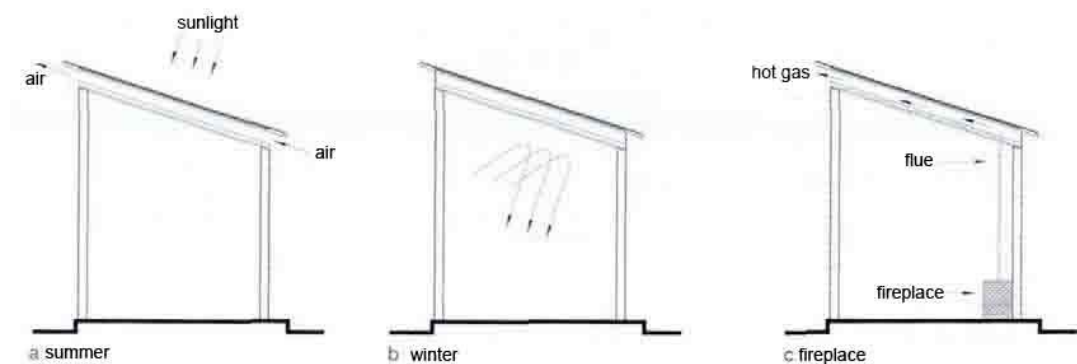


Figure 109 the operation of the vents in summer, winter, and when using fireplace (Zhang and Ren, 2013)

As shown in Figure 109, in hot days, the operable vents are open, the circulating air takes away the heat; in cold days, the operable vents are closed, Heat from the sunlight is absorbed by the roof boards, the radiated heat of the roof boards is stored by the light clay, conducted slowly inward through the roof sheathing. The roof board prevents the escape of radiant heat from the storage light clay. The heat radiated by the light clay is therefore trapped within the airspace, further heating the light clay. The heat of the storage light clay will take several hours to reach the interior of the building. This means that the room below remains comfortable through the day and receives slow, even heating for many hours after the sun sets. Such designs optimize heat gain and minimize heat loss during cold times, and avoid excess heat gain in hot times.

The traditional fireplace is not energy efficient, the most heat is taken away by the hot gas

through the flue. Ren connected the flue with the airspace in the roof, the hot gas go through the flue and the airspace, then go out from the operate vent, as shown in the Figure 109. The roof absorbs and stores the heat, and radiates inward. After putting out the fire and closing the operable vent, the roof still gives heat to the rooms below slowly for several hours. Such design improve the thermal efficiency of the fireplace.

Ren tested the thermal performance of his experimental houses in summer. When outdoor temperature is 34°C, the temperatures of interior surfaces of rammed earth wall and roof sheathing are the same, and the indoor temperature is 29°C.

7.6 Conclusions

Rammed earth construction has good thermal insulation and compressive strength. It is low-cost, sustainable and available in most locations worldwide. But the traditional Chinese rammed earth buildings often have poor lighting and ventilation. And they need to maintain regularly. For example, the plaster of the rammed earth wall should be renovated every three years. And the earth wall would melt when having strong wind driven rain or flood. The villagers admire the reinforced concrete frame houses with substantial and durable bricks, straight flat walls and big windows. It is one of the reasons that they want to demolish the old houses and build houses with concrete, brick, and steel. While these modern building materials have other shortcomings such as high price, unable dismantle, high environmental impact and embodied energy. Ren has remedied the shortcomings of traditional rammed earth house in his experimental houses. However, most rural residents in Anji County don't like the plain appearance of his experimental houses and they are not sure the durability performance. Furthermore, the shortcomings of the traditional earth buildings make them view the earth as a building material for the poor. So they have little interest in the rammed earth construction. So far the modern rammed earth techniques have not been popularized in Anji County.

On the other hand, for several rural environmentalists like Ren Weizhong, the natural vernacular construction also is a daunting prospect. Due to a lack of technological knowledge, Ren experienced difficulties and made mistakes. For example, he have reformed 'House 1' two times. Despite the enthusiasm there are few guidelines on how to design and build with these materials so that they meet the provisions of modern building codes, especially in temperate humid climates with strong wind driven rain such as occurs in Southern China (includes Anji).

Anji County is located in the Yangtse River delta economic area where rural residents have the highest income in China. They have financial ability to buy the durable modern materials like concrete, masonry, steel to replace natural materials. It may be a progress for them in despite of the environmental impact. However, in the vast rural area inland, due to limitation of economy, many farmers have to build with natural materials, especially earth.

Although Chinese have been working with earth and wood for structural use for thousands of years, we still often get their usage wrong. Indeed, there are many historical earth buildings still stand today, such as the condominiums of the Hakas in China. However, there are more earth buildings failed. For example, the collapsed earth buildings in 2008 Sichuan Earthquake. This is because there is not any systematic standardization of unfired earthen materials for these builders in China.

For long-term technology transfer in the vast rural China, we need a comprehensive suite of earth building standards that meet the requirements of a modern performance based building code. Furthermore, we could provide education and technical training, and develop semi-automatic machines and relevant manufacturing to decrease the labor strength of rammed earth construction.

8 Innovation of Rammed earth construction in rural China

8.1 Maosi Ecological Demonstration Primary School

In 2006, Wu Zhi Qiao team sponsored Maosi Ecological Demonstration Primary School in Maosi Village, Qinyang City, Gansu province.

Wu Zhi Qiao (Bridge to China) Charitable Foundation is a charity registered in Hong Kong. Through encouraging volunteers, especially university student volunteers from Hong Kong and Mainland China, to design and build footbridges and village facilities in remote and poor villages in the Mainland with green concepts. (*What is Wu Zhi Qiao*, 2007)



Figure 110 Maosi Ecological Demonstration Primary School (Ng and Mu, 2007)

Data of the project

Size: 10,600 square meters

Cost: Approximately US\$ 157,281

Unit Cost: Approximately 15 USD /m²

Unit Cost of Classrooms: 422HKD/ m², approximately 42 USD /m²

Responsible Party: Edward Ng, Jun Mu

Heritage Architect: Edward Ng

Contractor: Mao Jiaxiong

Date of Completion: July 2007 (UNESCOBKK, 2009)

Background

The Loess Plateau region is in the upper and middle reaches of China's Yellow river. The soil of this region has been called the most highly erodible soil on earth. The Plateau generally has a

semi-arid climate. The winter are cold and dry, while summer are very warm and in many places hot. Centuries of deforestation and over-grazing, have resulted in degenerated ecosystems, desertification, and poor local economies. (*Loess plateau*, 2016) In order to improve the living standards and develop low-cost ecological construction in the region, Wu Zhi Qiao Charitable Foundation sponsored Maosi Ecological Demonstration Primary School.



Figure 111 Xifeng and China's Loess Plateau region (Mu and Ng, 2006)

Research and rethinking of the traditional building technology

Under the extreme conditions, local residents have learned how to stay in harmony with nature over thousands of years. They created cave - a pattern of ecological housing. But in recent years, with the changing of the lifestyle and society, these traditional construction methods have gradually been abandoned. Concrete, metal, and bricks are used to replaced earth and wood in the construction. But these self-building concrete masonry homes can't adapt to the formidable natural conditions. They can't provide an energy- and cost-effective indoor climate. And the production and construction of concrete and bricks exploits the resource and pollutes the environment.

Facing with the backwardness of the economy and building techniques, we should develop low-cost ecological buildings in the rural place of Loess Plateau area. After a study of local loam cave homes, the experts found that the traditional building techniques contain a lot of valuable eco-design elements which can be applied in the design of the school.

The Principles of the appropriate ecological design

The major focus of the Maosi Ecological Demonstration Primary School was to promote sustainable natural construction and lifestyle. Their design principles can be summarized as follows:

1. Reduce energy consumption

Avoid using high-polluting building materials such as baked clay bricks and cement. And reduce the energy consumption and pollution generating in the construction process. In order to balance indoor climate and reduce heating and cooling costs, we should design passive solar buildings. In passive solar building design, windows, walls, and floors are made to collect, store, and distribute solar energy in the form of heat in winter and reject solar heat in the summer. (Doerr, 2012) The

key to designing a passive solar building is to best take advantage of the local climate performing an accurate site analysis. Elements to be considered include window placement and size, and glazing type, thermal insulation, thermal mass, and shading. (Norton, 2014)

2. Increase the use of renewable energy

Reduce the demand for such fossil fuels as coal, oil and natural gas, increase the use of renewable energy school such as solar and wind energy.

5. Use local natural building materials

Take full use of local natural materials such as earth, wood, straw, reeds, etc. These materials are low-cost, reusable and biodegradable. Unbaked earth can be recycled an indefinite number of times over an extremely long period. The earth of abandoned houses can be reused after soaking in water. Plant materials like wood, straw and reeds also can be reused, old rotted plant materials can be used as manure. So they never become building waste that harms the environment.

4. Self-build construction

The processes involved should be labor-intensive and require only inexpensive tools and machines, they should be ideal for self-build construction. Provided the building process is supervised by an experienced individual, the improved traditional building techniques can usually be executed by non-professionals. For example, the planning should be adapted to the local topography, to avoid using excavator.

Traditional homes in the Loess Plateau

Loess Plateau is one of the regions with thickest loess sediments in the world. Loess as the main building material has been widely applied in a traditional building in the Loess Plateau because of its excellent thermal insulation for thousands of years. The earth that surrounds the indoor space serves as an effective insulator keeping the inside of the structure warm in cold seasons and cool in hot seasons. Consequently, very little heating is required in winter, and in summer, it is as cool as an air-conditioned room. The sustainable design of these earth shelters is a reflection of a key traditional Chinese concept – the harmonious relationship between human beings and nature. (Yaodong, 2016)

The particular form of earth shelter dwelling common in the Loess Plateau is the well-known Yaodong (Chinese: 窑洞) or “house cave”. They are generally carved out of a hillside or excavated horizontally from a central “sunken courtyard” or “earth-vaulted houses”. Earth-vaulted homes are built where the construction of underground yaodong is not allowed, they are built wholly or partially outdoors, with an arched structure inspired by the underground dwellings. The new vaulted adobe homes of this type are now common among farmers in the area. (Yaodong, 2016)



Figure 112 Sunken cave (left), Hill-side cave (middle) and stand-alone earth-vaulted houses (right) (Ng and Mu, 2007)

Now the villagers still keep the tradition of self-building and community participation. The households invite their neighbors to help in the construction of their homes. The construction was usually supervised by an experienced carpenter in the village. Since the processes involved are labor-intensive and require only simple tools, the construction techniques can usually be executed by non-professionals. Except for earth, other natural materials like straw, reed, wood, stone, etc. are also used in the construction. Each material has its specific function and the corresponding construction techniques. For example, the humid loess is compacted into blocks in the mold, after drying about 40 days, become adobe for masonry construction. Because the fiber increases the binding force of the earth, moreover, the appearance of cracks is reduced. The fibers such as cut straw or reeds are added to the earth to reduce the shrinkage ratio. Since the volume of air entrained in the pores of a material and its humidity are relevant for the thermal insulation effect. The lighter the material, the higher its thermal insulation, and the greater its humidity level, the lower its insulating effect. Porous substances such as straw, reeds, cork and other light plant matter are added in the earth for increasing its thermal insulation. Because stones have better compressive strength and moisture resistance than earth, they are used for the foundation construction which prevents rising damp from ground moisture.

The Loess Plateau generally has a climate that cold and dry in winter, very warm in summer and in many place hot, and a large temperature difference between day and night. In such climate, thermal capacity of buildings is very important. In the comparison between a solid wall of rammed earth with straw and baked bricks, the former has better thermal insulating effect, lower embodied energy and price.

In recent years, local vernacular building culture, yaodongs has declined. People prefer rebuild their home with durable materials like brick, cement and steel. There are prejudices against earth as a building material. Most rural residents think that earth is only for the poor. The reason is that compared to conventional industrialized building materials, earth has four disadvantages. However, this disadvantages can be improved by correct design and craftsmanship.

1. Earth mixtures shrink when drying

Due to evaporation of the water used to prepare the mixture (moisture is required to active its

binding strength and to achieve workability), shrinkage cracks will occur. The linear shrinkage ratio is usually between 3% and 12% with wet mixtures (such as those used for mortar and mud bricks); and between 0.4% and 2% with drier mixtures (used for rammed earth, compressed soil blocks). Shrinkage can be minimized by reducing the clay and water content, by optimizing the grain size distribution, and by using additives. (Minke, 2013)

2. Earth is not water-resistant

Earth must be sheltered against rain and frost, especially in its wet state. Earth walls can be protected by roof overhangs, damp-proof courses, appropriate surface coatings, etc. (Minke, 2013)

3. Earth is not a standardized building material. Depending on the site where the loam is dug out, it will composed of differing amounts and types of clay, slit, sand and aggregates. Its characteristics, therefore, may differ from site to site, and the preparation of the correct mix for specific application may also differ. In order to judge its characteristics and alter these, when necessary, by applying additives, one needs to know the specific composition of the earth involved. (Minke, 2013)

4. Earth construction is supposed to be worse affected than other types of construction in earthquake because most houses with earth walls cannot withstand any earthquake. Approximately 810,000 people died in collapsed yaodongs in the 1556 Shaanxi earthquake. While many historical earth buildings have withstood several strong earthquakes in recent centuries, for example, the Fujian Tulou (condominiums of Hakas in China). So that it was not the use of earthen materials as such that led to the collapse of such buildings during earthquakes, but rather incorrect structural designs and bad craftsmanship. (Minke, 2013)

The site selection and the master plan design

The site is leaning against hills on the north, western and eastern sides and facing to Pu River on the south side, which is selected according to Fengshui.

One of the major principles of fengshui is leaning against mountains on the north side, and facing water on the south side. a) Fengshui masters think a house leaning against the mountains and facing the rivers is auspicious and can bring good luck for people living in it. Over a region, the presence of water body can create a more moderate climate and will impact upon the temperature of the surrounding areas. These effects are due to the fact that water gains and loses heat more slowly than the land. The water body also sends moisture into the air through evaporation. This atmospheric moisture captures heat from the sun, making the air around a water body warmer than areas further away. b) Most of China's territory is located to the north of the Tropic of Cancer. A house facing south can easily absorb the sunshine and avoid the cold north winds in winter. This is a benefit to people's health.

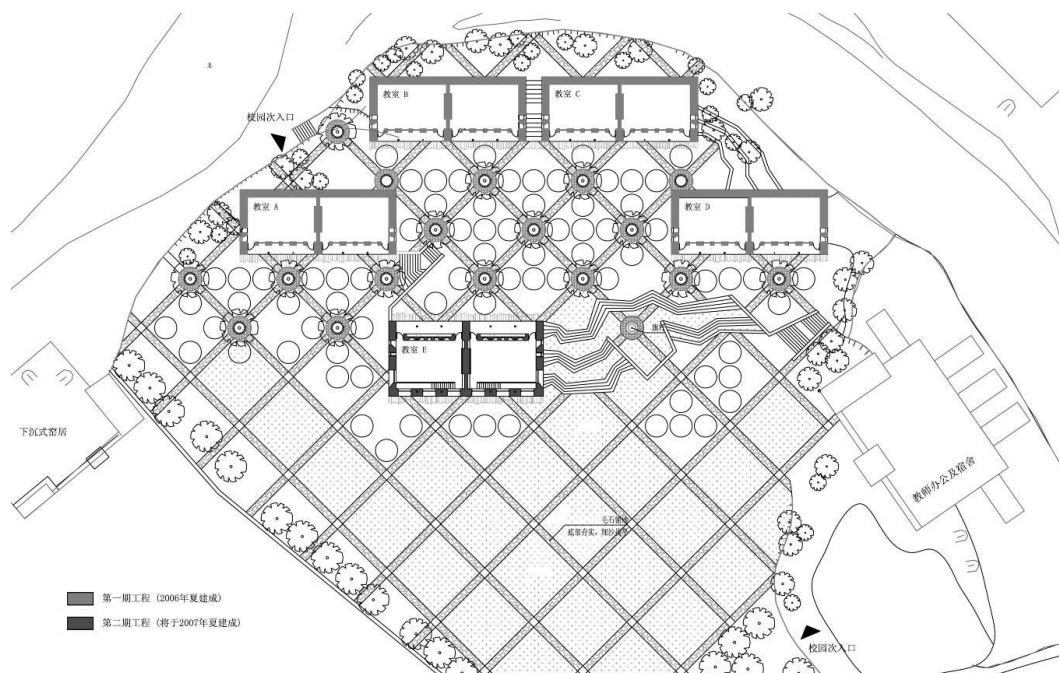


Figure 113 Materplan of Maosi Ecological Demonstration Primary School (Ng and Mu, 2007)

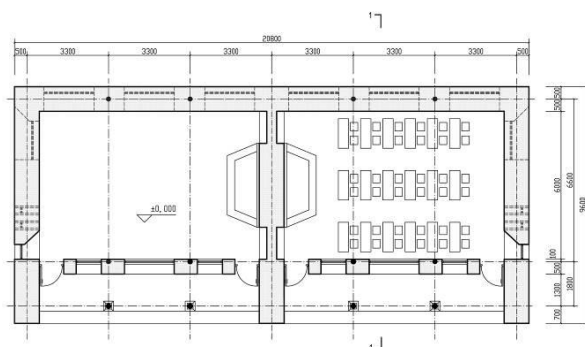


Figure 114 Plan of classrooms (Ng and Mu, 2007)

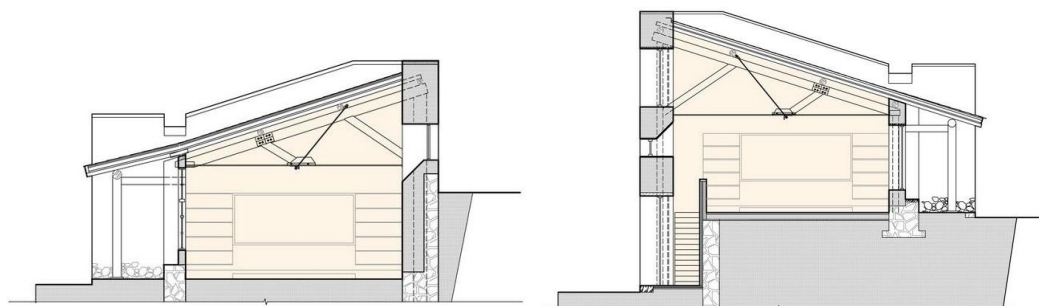


Figure 115 Section view of classrooms A-D (left) and Section of Classroom E (right) (Southern Metropolis Daily, 2008)

Some classrooms leaning against the hillsides are semi-underground, to lessen the wall surface exposed to the cold winds and to take advantage of the warmth of the ground in winter.

Structure

The structure of classrooms is timber frame with steel tension tie and adobe masonry. The roof is mono-pitched. Steel tension ties increase the span distance. There is not any column in the classroom.



Figure 116 Steel tension ties increase the span distance. (Ng and Mu, 2007)



Figure 117 Classroom (Ng and Mu, 2007)



Figure 118 Playground and garden (Southern Metropolis Daily, 2008)



Figure 119 The open space in front of classrooms A-D (Ng and Mu, 2007)

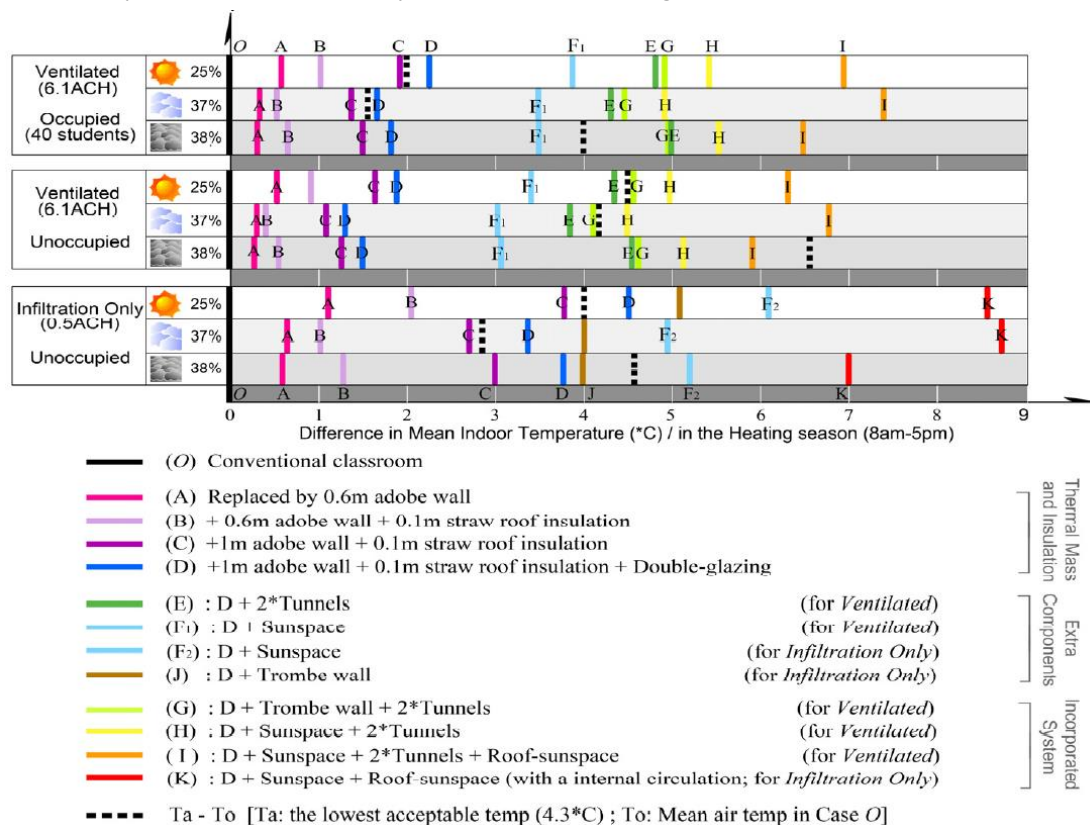


Figure 120 The front elevation of the primary school (Southern Metropolis Daily, 2008)

Passive solar design

In passive solar building design of the school, windows, walls, and floors are made to collect, store and distribute solar energy in the form of heat in the winter and reject solar heat in the winter. Adobe walls, double glazing window, straw roof, sunspace and Trombe wall, these building techniques were considered to be used in the passive design. The architects used Tas (a computer program) to make a comparison of the thermal contribution of these techniques (Table 1), an analysis of natural ventilation (Figure 121) and Relationship between construction cost and thermal performance of these techniques (Table 2).

Table 1 Comparison of the thermal contributions from the developed techniques, based on mean indoor temperatures in different sky conditions (Mu and Ng, 2006)



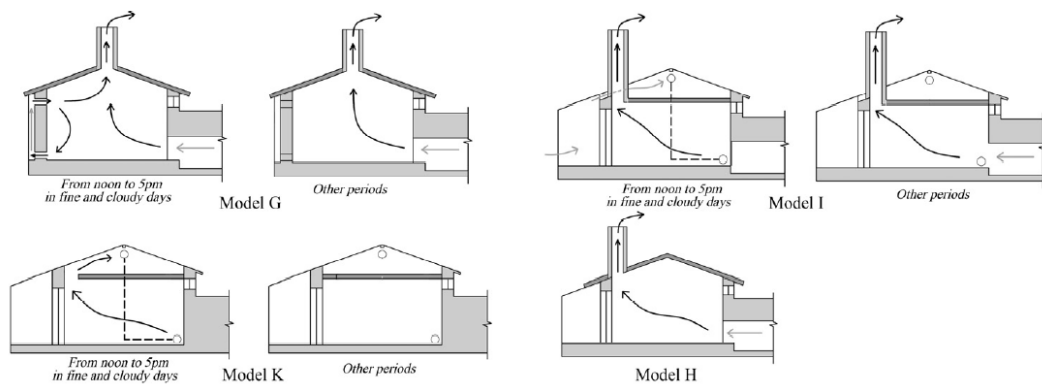


Figure 121 Incorporated system models as optimized (Mu and Ng, 2006)

Table 2 Relationship between construction cost and thermal performance of the developed techniques (Mu and Ng, 2006)

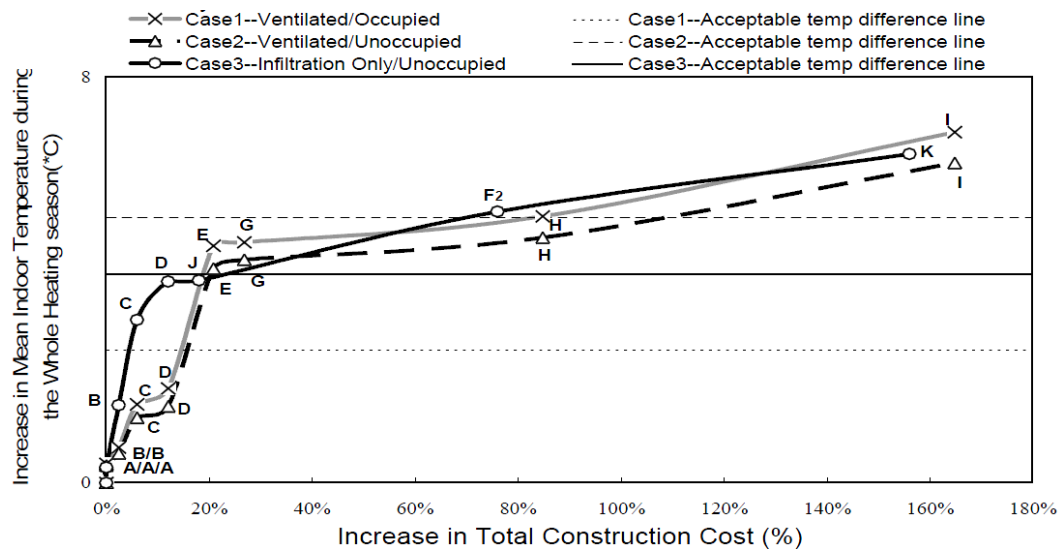


Figure 122 A semi-underground gable (left), South porch (right) (Ng and Mu, 2007)

According to the analysis, the designs of 1-m-thick transverse walls (Figure 109), 0.1 m straw roof and double-glazing window can achieve the best thermal environment with the limited funds. The south porch (Figure 109) can be converted into Trombe wall in the future. In order to reduce the heat loss of window and door, the window and door frame is wood, the airtight seals at junctions of windows and doors frame to optimize thermal insulation. A layer of polystyrene was added to the traditional roof for improving the thermal insulation. The traditional roof is made of reed curtains, lightweight straw loam and clay tiles. Lightweight straw loam has good thermal insulation and waterproofing, but it shrinks and cracks after longtime insolation which leads to the leakage of rain. In the roof of new classroom, the polystyrene roof insulation was added between clay tiles and lightweight straw loam.

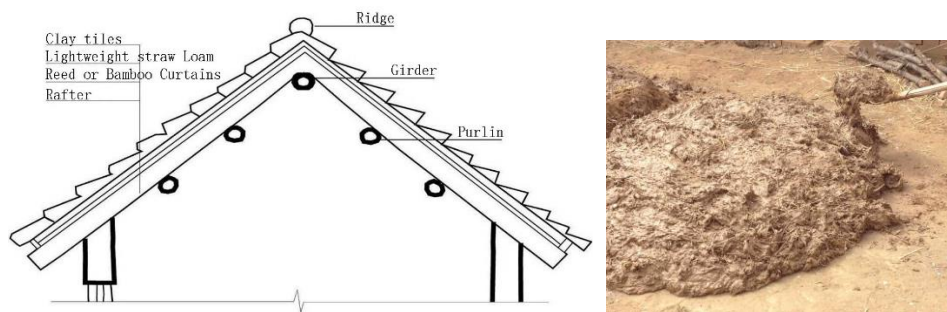


Figure 123 Cross section of local typical roof (left); lightweight straw loam (right) (Ma, 2013: 58)



Figure 124 cover reeds curtain on the rafter (Ng and Mu, 2007)

The building area of each classroom is 54m² (6 × 9m), can accommodate fifty students. When the classroom was occupied by 50 students, the air temperature in classroom also increases because of the heat produced by human body.

Finally, while the diurnal variation of the outside air temperature was 21°C, the air temperature

inside the new adobe classroom varied only by 2°C; while in the old baked brick classroom, the variation was 8°C. (Table 3)

Table 3 Diurnal air temperature variation of the outdoor, conventional classroom and new classroom (Ng and Mu, 2007)

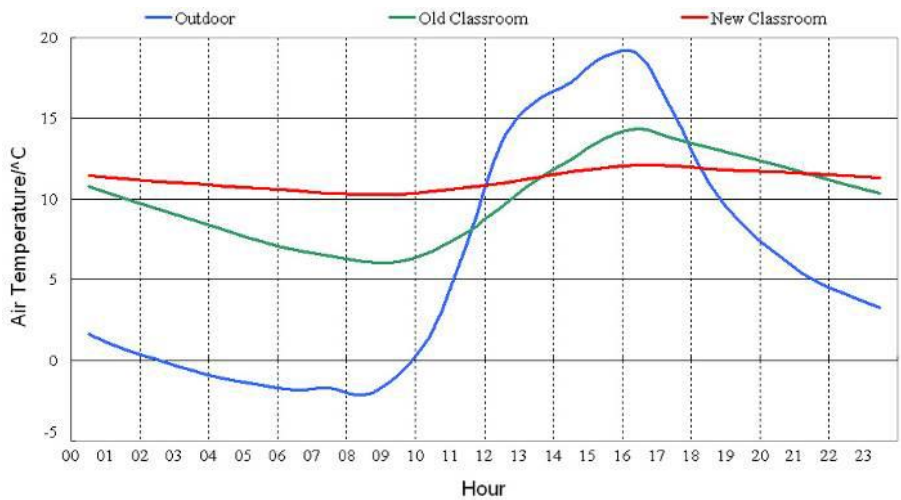
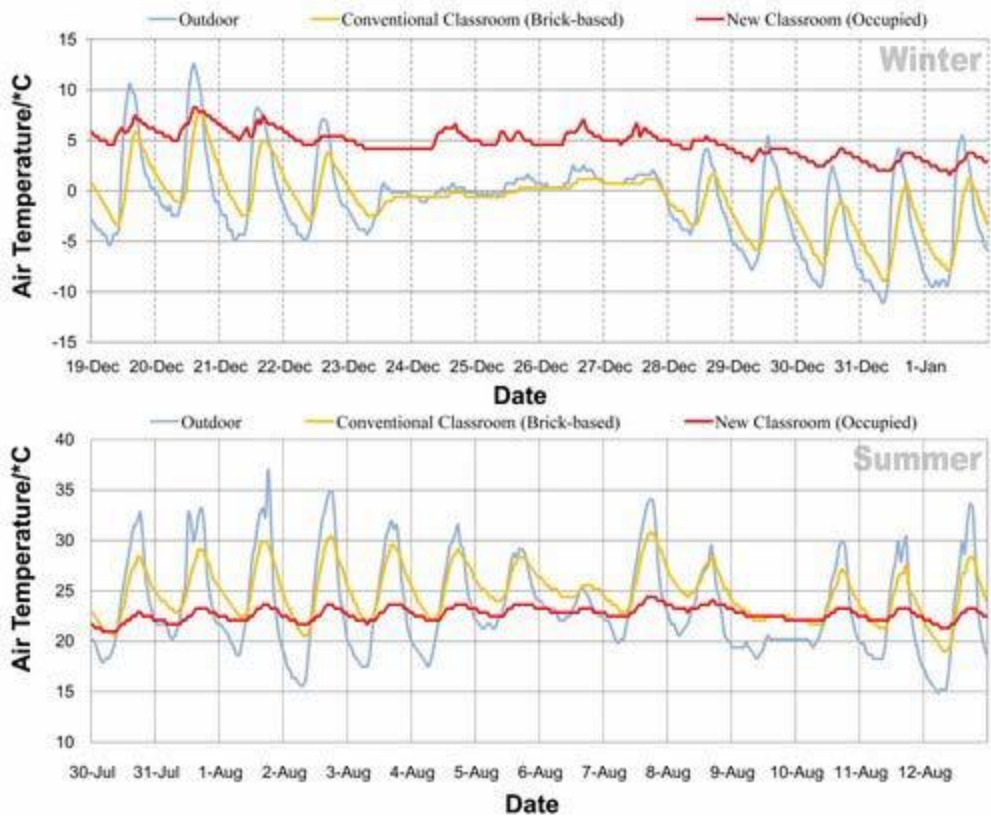


Table 4 Seasonal air temperature variation of the outdoor, conventional classroom (brick-based) and new classroom (Huang, 2008)



Chamfered recessed window

Because the gable ends are too thick, chamfered recessed windows were designed to optimize the lighting of the classrooms.



Figure 125 Chamfered recessed windows (Ng and Mu, 2007)

Mixture for Adobe bricks

The quest for suitable soil

In concrete construction, sand and gravel are the structural aggregates, while cement and water make the glue. (*Concrete: Scientific principles*, no date) In rammed earth construction, sand and gravel are also the primary aggregates, and clay and water act as the glue. The slit is composed of microscopically small particles of pulverized rock. Particles of the slit are not chemically active and sticky, don't contribute to the binding together of the other particles nor to the ultimate strength of the wall. They only contribute to the overall density of a wall. (*Earth structure*, 2016)

Loess is an aeolian sediment formed by the accumulation of wind-blown silt, typically in the 20–50 micrometers size range, twenty percent or less clay and the balance equal parts sand and silt that are loosely cemented by calcium carbonate. It is usually homogeneous and highly porous and is traversed by vertical capillaries. Loess is highly erodible soil due to its high slit and fine sand content. (*Loess*, 2016) In order to raise the strength and water resistance of adobe bricks, coarse sand from river bank was added to the earth.

Manufacturing adobe bricks

The handmade bricks were produced with simple tools shovel and wooden moulds by the villagers. Firstly, spread plant ash or coal dust on the mold to facilitate take out. Then shovel the mixture into the brick form and ram it. (Figure 126) Finally, drying the adobe for about 40 days, and avoiding direct - sun exposure.



Figure 126 The production of adobe bricks (Ma, 2013: 54)

Laying adobe bricks

The adobe bricks were laid with either straw-earth mortar. To avoid shrinkage cracks inside the mortar during drying, the mortar contains sufficient quantities of coarse sand. The clay content varies from 4% to 10%. Earth blocks can be cut easily by hand-saws.

Weather protection of earth buildings

Loam plaster

Because of increased erosion, shrinkage cracks in earth surfaces exposed to rain should be prevented. Shrinkage during drying depends on water content, on the kind and amount of clay minerals present, and on the grain size distribution of the aggregates. The addition of sand or larger aggregates to a loam reduces the relative clay content and hence the shrinkage ratio. The shrinkage ratio of loam can be reduced by the addition of fibers such as cut straw and bamboo. (Minke, 2013) Hence, the exterior walls and interior walls of classrooms were plastered with straw loam plaster. The straw loam plaster contains adequate coarse sand and cut straw.

Lime plaster

The earth surfaces can be made more resistant to environmental forces. For instance, the structural measures shelter them from these forces, and the exposed earth surfaces can be protected or hardened with plaster or paint.

In the project, for the side walls of classrooms exposed to the rain and earth elements left unsheltered during construction. There is the danger of rainwater penetrating the earth, causing swelling and erosion. It is necessary to add stabilization against water erosion. For the clay loess, lime as stabilizers is good. With lime as a stabilizer if there is sufficient humidity, then an exchange of ions take place in the earth. The calcium ions of limes are exchanged with the

metallic ions of the clay. As a result, stronger result, stronger agglomerations of fine particles occur, hindering the penetration of water. Furthermore, the lime reacts with the CO₂ in the air to form limestone. While the lime may decrease the compressive strength of earth mixture. (Minke, 2013) Lime plaster was used on the exposed exterior straw loam plaster of classrooms for making surfaces water-repellent. The lime plaster consists of 1 part hydraulic lime and 3 to 4 parts sand.

Protection against rising damp

A damp-proof course, stone masonry can protect adobe walls from rising damp. The adobe walls of the classrooms were built on 1-m-thick 1.5-m-height stone masonry.



Figure 127 Stone masonry as a damp-proof course (Ng and Mu, 2007)

Self-building

The experienced masons and carpenters and architects from WZQ team work together to make the vernacular natural construction meet the requirements of a modern performance. The villagers participated in the construction. The tools used in construction are very simple such as a shovel, handsaw, mold, etc. The duration of the project is about two months.

Low-cost and environmental friendly

The building materials and construction method are environmentally friendly. Except for steel frame, glass, polystyrene roof insulation, all the materials such as pine, earth, reed, straw are reusable and renewable. The clay roof tiles were recycled from the abandoned old houses in the village. The construction cost of the classrooms is 378 yuan/m², while the construction cost of a concrete building usually is 1000-1200yuan/m².

The state of the project

The school was abandoned due to damage.



Figure 128 (left) The melted gable (Ma, 2013: 74)

Figure 129 (right) The melted gable (Ma, 2013: 73)

The both gables ends and the middle transverse walls of the classrooms were exposed to the rain for a long time, and the coating system was failed to prevent them from eroding. The lesson learned from the failure is that there should be broad overhangs on the roofs keeping the rain away from the adobe walls.



Figure 130 Damp and mildew at the foot of the gable (Ma, 2013: 74)

Due to excessive thickness of the gables and inadequate lighting and ventilation, it took too much time for the vapor diffusion from inside to the outside of the walls, which led to the damp and mildew at the foot of the gables.

8.2 Village Rebuild Demonstration Project in Maan Qiao Village, Sichuan

The Foundation started its first village rebuild demonstration project in Sichuan after the earthquakes in 2008. The project was to help villagers rebuild their homes. The project aimed at exploring a way to sustainable reconstruction in the light of local conditions. The improvement of traditional rammed earth technique and the study on standardization have formed a series of technical measures, which are economical and practical, easily operable, and can effectively improve earthquake resistance and durability.

On August 30, 2008, 6.1 magnitudes of panzhihua earthquake occurred in Sichuan and Yunnan border, made the region become another heavy disaster zone after the earthquake in western Sichuan. The Maan Qiao Village located in Xinan Dai Township Huili County Liangshan Prefecture Sichuan Province is the most affected village in this region. The buildings in the village were damaged severely. Facing with the soaring price of conventional building materials, shortage of fund and blocking traffic, the reconstruction was begun hard. Given these challenges, in October 2008, MOHURD (Ministry of House and Urban- rural Development of People's Republic of China) commissioned Wu Zhi Qiao Charitable Foundation to organize the post-earthquake reconstruction of Maan Qiao Village.

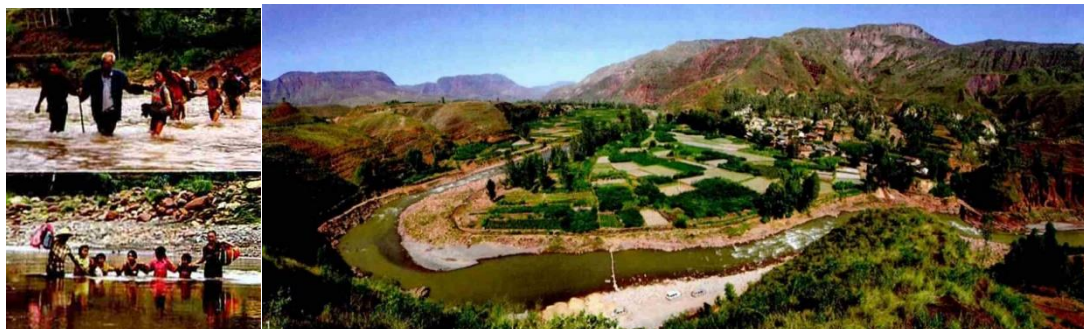


Figure 131 Maan Qiao Village (Mu, Wan, Zhou, Ng, Ma, and Yang, 2013)

Maan Qiao Village is surrounded by a river and mountains. The single-plank bridge is the only way to go out. And the bridge was washed away by flood water in the rainy season every year. The bridge was damaged by the earthquake, the villagers had to ford the river.



Figure 132 The damaged traditional rammed earth houses (Mu, Wan, Zhou, Ng, Ma, and Yang, 2013)

Problem and challenge

Maan Qiao Village is cut off from the outside by a river and mountains. Most traditional rammed earth houses were collapsed in the earthquake. Villagers lost faith in the seismic performance of rammed earth house. However, the conventional brick-based construction is not affordable for the villagers. Their average annual income is only 1000 yuan. Due to the blocking transportation, the industrial building materials couldn't be freighted in. On the other hand, abandoning the earthquake-damaged houses would produce a large amount of building waste and rebuilding conventional houses in a new location would occupy farmland, which is not sustainable.

Solution

The old houses are a blend of timber frame and rammed earth walls. The timber frames of most houses were not damaged by the earthquake. The architects and engineers of WZQ charitable foundation developed an earthquake-resistant rammed earth construction techniques based on local rammed earth construction. So people can recycle the earth of the collapsed walls and restore their houses according to the new building techniques. In order to promote this sustainable reconstruction mode, the Foundation provide technical training and fund to people who wanted to practice it.

Improvement and standardization of traditional construction techniques

Maan Qiao Village is located an earthquake-prone area. People have developed an earthquake-resistant construction system based on rammed earth and timber framework, which have been widely used in the area. However, due to the urbanization and the population decline in rural China, the traditional craftsmen are gradually disappeared and most traditional earthquake-resistant techniques are lost. What followed was, in recent years, without the guidance of craftsmen, many people built large openings in the rammed earth wall regardless of the anti-seismic performance, which is the main reason of damages.

To enhance the seismic performance of traditional rammed earth construction, the architects and engineers researched the damaged houses and developed an anti-seismic rammed-earth village house construction system. Wu Zhi Qiao Charitable Foundation issued a handbook '*Sichuan Anti-Seismic Rammed-Earth Village House DIY Construction Manual*' (Figure 133) in 2009. To help the rural residents better understand the guideline, it is defined clearly by a large number of images. The guideline defines site selection, structural design, passive solar design, ventilation and lighting, construction method, preparation of building materials, the layout of village houses and standardization of construction tools, etc.



Figure 133 'Sichuan Anti-Seismic Rammed-Earth Village House DIY Construction Manual' issued by Wu Zhi Qiao Charitable Foundation (Zhou, Mu and Yang, 2009)

Anti-seismic earthquake designs

The wood or bamboo pins and columns in the rammed earth wall enhance the structural integrity, as shown in Figure 134.



Figure 134 The vertical wooden pin and columns in the wall (Zhou, Mu, and Yang, 2009)



Figure 135 Formwork being erected (Zhou, Mu, and Yang, 2009)

The formwork is removed and re-erected horizontally step by step. Earth is rammed in layers from 50 to 80 cm high, forming courses of that height before the formwork is moved. (Figure 135)



Figure 136 the builder was smoothing and patting the wall firm (Zhou, Mu, and Yang, 2009)

After removing the formwork, the builder smoothed and patted the wall firmly. (Figure 136)



Figure 137 Various cast iron ram with handles (left) and rammers (right). (Zhou, Mu, and Yang, 2009)

On every layer of rammed earth, horizontal wooden or bamboo tie bars were pre-buried along the wall to enhance the shear strength of the wall. There are at least three tie bars on each layer of wall. At the corners of the wall, the tie bars of two directions were overlapped and fixed with iron wire. As shown in Figure 138.





Figure 138 Horizontal wooden tie bar along the wall (Zhou, Mu, and Yang, 2009)

Ring beam in the wall

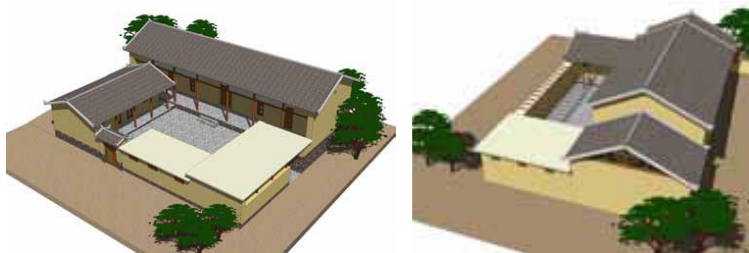
The wooden ring beam was set at the top of the walls to increase the structural integrity, as shown in Figure 139. The tenon and mortise joints of wooden ring beam were fixed with nails.



Figure 139 Ring beam (Zhou, Mu, and Yang, 2009)

Layout of village house

The architects worked together with the villagers designed 12 housing prototypes for choice and reference.



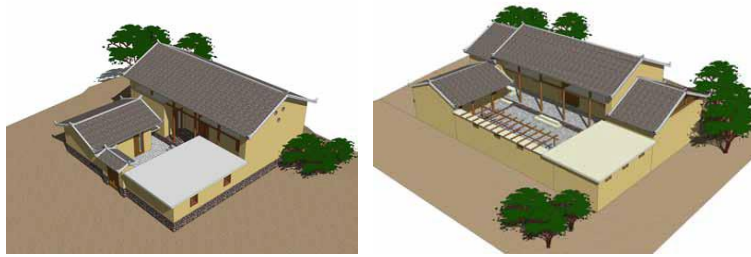


Figure 140 Housing prototypes (Zhou, Mu, and Yang, 2009)

Recycle building waste and use local building materials

About 90% of building materials are recycled from the building waste generated by collapsed dwelling houses and dilapidated buildings, the rest are local natural materials including bamboo, sand, and stone.

Construction cost

While the villagers in the Maan Qiao Village can rebuild a house on the base of the original house, they only need to rebuild the damaged part of the house by using building waste and local natural materials. Due to the mutual-aid construction mode, there was little labor cost. So the building cost is very low. The average construction cost per m² of Maan Qiao Village housing is about 4.47 yuan.

Thermal performance

The climate in Maan Qiao Village is cold in winter and hot in summer. The annual maximum indoor temperature of the rammed earth home is 5°C lower than the conventional brick-concrete house.

Training

The professionals facilitated and guided the design process of a demonstration home and supervised the building process. The villagers learned the building techniques through hands-on training on the construction site. By the end of the construction, the local team (made up of the villagers) will have designed their very own rammed earth home, adapted to their circumstances.

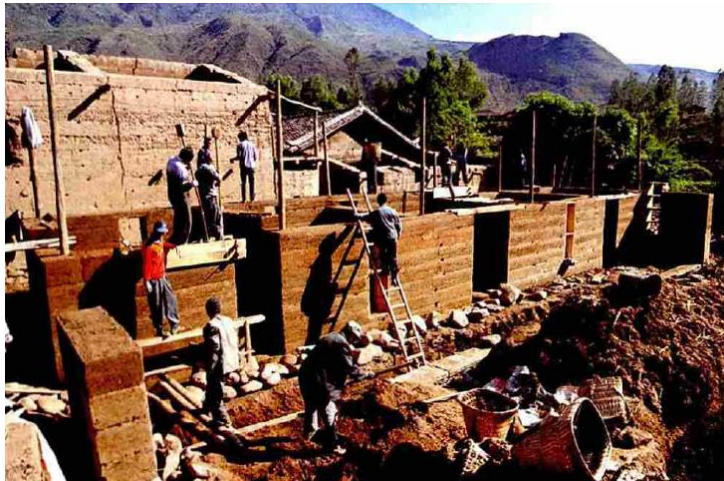


Figure 141 The demonstration project (Mu, Wan, Zhou, Ng, Ma, and Yang, 2013)

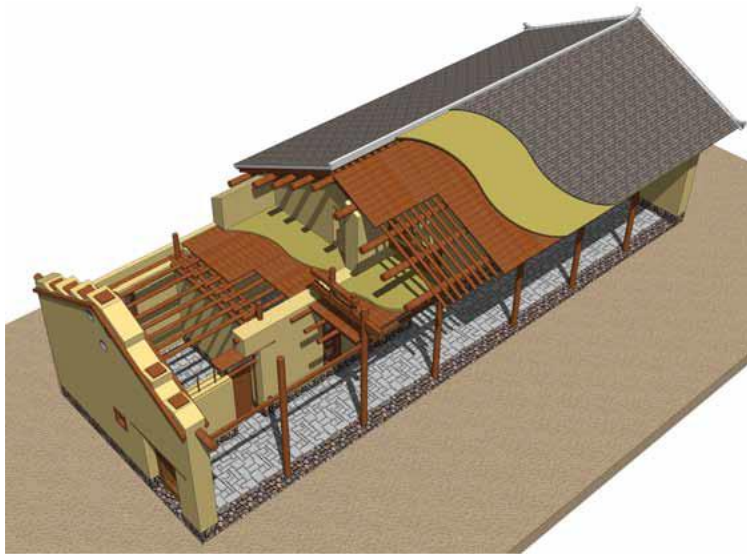


Figure 142 The structure of the demonstration home (Zhou, Mu, and Yang, 2009)

Funding

Against the problem of farmland occupation in the post-earthquake reconstruction, the Wu Zhi Qiao Charitable Foundation provided different levels of funding to homebuilders. In order to encourage villagers to rebuild on the original site, the funding for people constructed on farmland is only 20% of that for people rebuild on the original site.

Short duration

Provided guidelines, prototypes, training and funding, people designed and rebuild homes independently. Villagers linked up and organized a construction mutual-aid team. They completed all the 33 homes of the village (Figure 143) in three months. The duration of rammed earth construction is much shorter than that of conventional brick masonry construction.

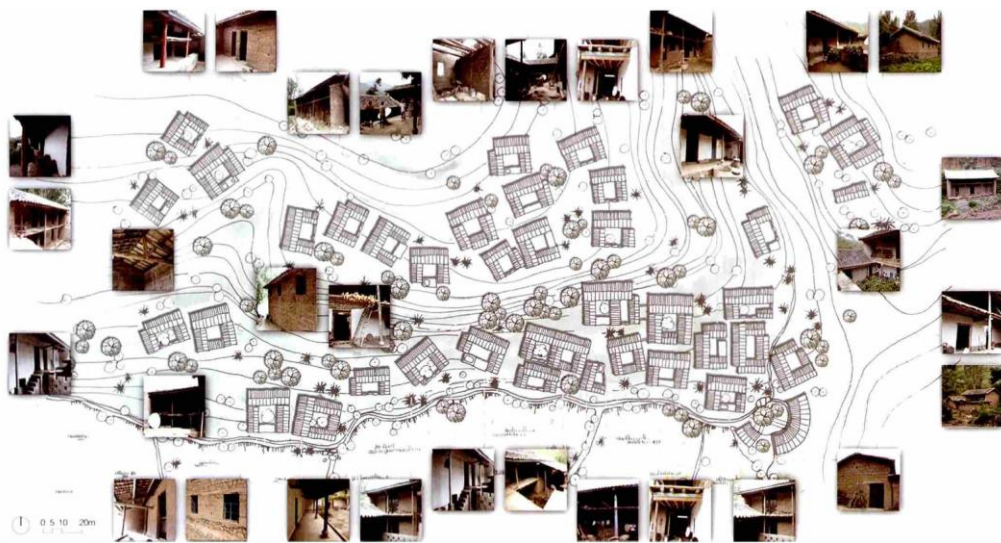


Figure 143 33 new homes in Maan Qiao Village (Mu, Wan, Zhou, Ng, Ma, and Yang, 2013)

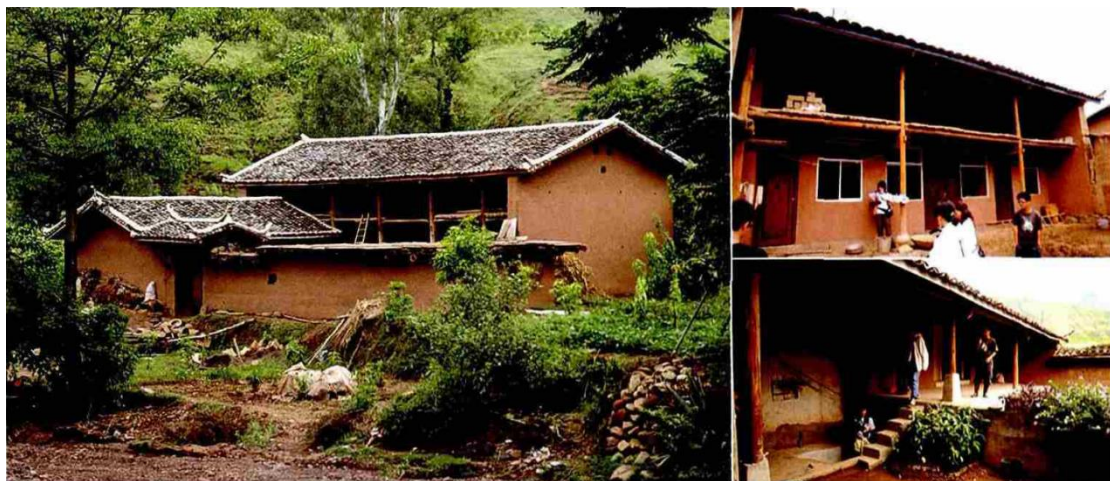


Figure 144 One of the new homes (Mu, Wan, Zhou, Ng, Ma, and Yang, 2013)

Villagers Activity Center and community development



Figure 145 Village activity center (Mu, Wan, Zhou, Ng, Ma, and Yang, 2013)

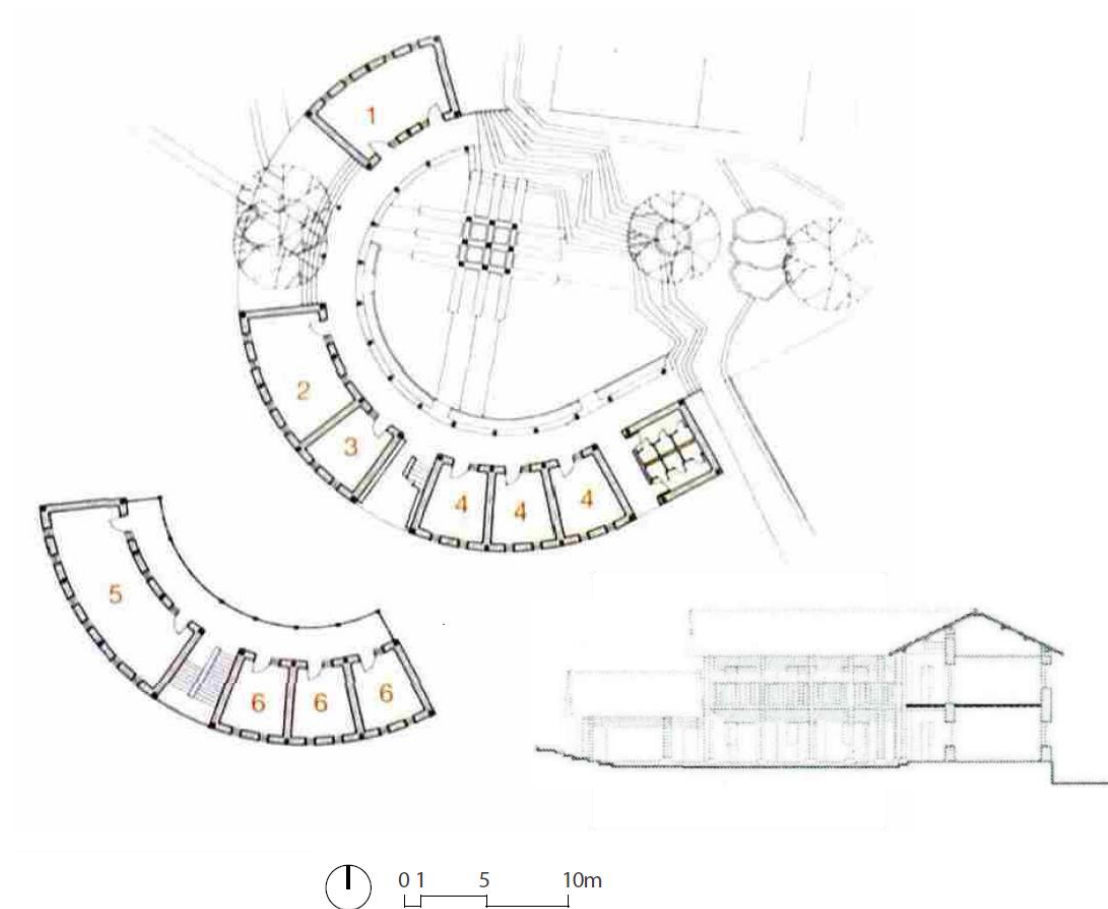


Figure 146 Plan and section of Villagers Activity Center

1. Clinic 2, kindergarten 3. Shop 4.village committee office 5.library and multi-function hall 6, living quarter (Chi, 2011: 68)

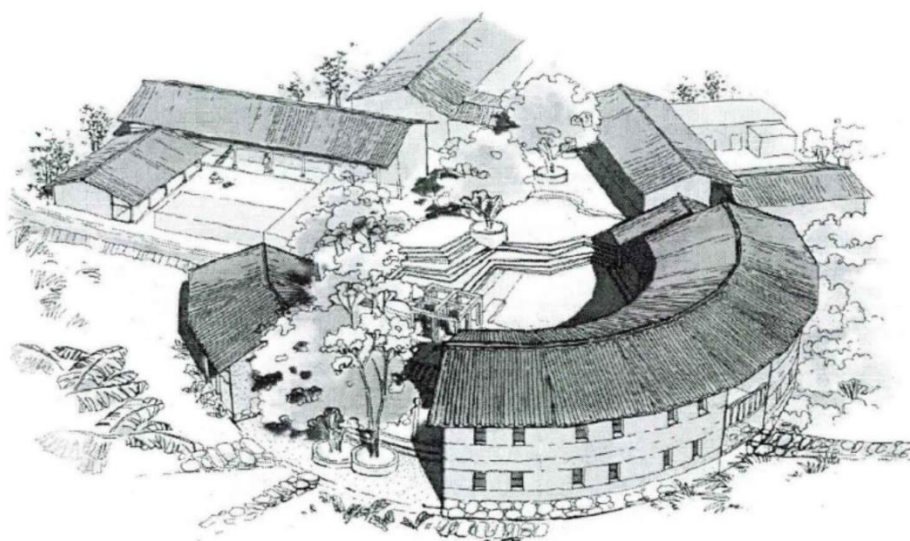


Figure 147 Aerial view of Village Activity Center (Chi, 2011: 68)

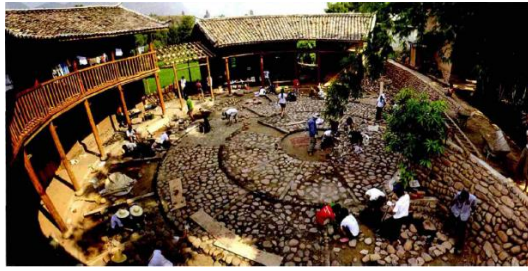


Figure 148 Village Activity Center (Mu, Wan, Zhou, Ng, Ma, and Yang, 2013)

The activity center is rammed earth building, constructed by the villagers and volunteers. The severe brain-drain of traditional village is due to the lack of public service. In order to improve medical care, health education, agriculture, and construction technology in Maan Qiao Village, Wu Zhi Qiao Charitable Foundation sponsored the Village Activity Center with political commitment and local villagers' support. It functions as village committee office, kindergarten, library, clinic, activity center and agriculture and construction training center. The training center will provide the villagers up-to-date information of rammed-earth construction for long. The villagers could become expert of local rammed earth construction, establish their own project management office and take the work forward on their own.

Modern Rammed Earth Construction

In order to promote rammed earth construction in China, the Ministry of Housing and Urban-Rural Development, P. R. C. committed Xi'an University of Architecture and technology to launch 'Modern Rammed Earth Green Housing Construction Research and Demonstration Project' based on Huining County, Gansu Province in 2011. With help from International Center for Earth Construction in France, Xi'an University of Architecture and Technology first introduced modern rammed earth construction theory to China. Through a large number of basic experiments, they adapt the theory to the poor rural area in China, forming a construction system.

In the new system, the ramming tool is automatic, the formwork is stable and easy to remove and re-erect and the ratio of earth mixture is determined more scientifically, which effectively improve the durability and safety performance of rammed earth building. (Mu, n.d.)

The first modern rammed earth rural house in Dingjiagou Village, Huining County, Gansu Province was completed in July 2007. Its good thermal performance is the same with the traditional rammed earth construction. And its structural safety and durability were effectively improved. Its building cost is about 2/3 of conventional brick masonry construction.

The modern rammed earth construction is being promoted in many poor rural areas in China. A lot of demonstration houses are being built in various villages.



Figure 149 Home being built in Huining County (left), the demonstration housing project in Heiyagou Village, Fuping County (middle), the completed demonstration housing project in Heiyagou Village, Fuping County (right) (Mu, n.d.)

8.3 Conclusions

In the vast poor rural area of China, the requirements for shelter cannot be met with industrially produced building materials such as fired bricks, cement concrete and prefabricated panels of various compositions and corresponding building techniques, since neither the productive capacity nor the necessary financial resources are available. The only seemingly feasible solution is to use natural, locally available materials and appropriate skills and tools while integrating self-help techniques, all of which make earth the ideal building material. (Minke, 2013)

The traditional rammed earth construction has shortcomings in duration, anti-seismic performance, waterproofing, lighting and ventilation limited by the area of openings. It is the reason that rural residents want to use durable industrialized building materials like baked brick to rebuild their house, even if it increases their economy burden.

However, it has been proved that in many cases, it was not the use of earthen materials that led to these shortcomings, but rather incorrect structural designs and bad craftsmanship. The modern rammed earth construction system proposed by Mu Jun improves the building techniques, structural design and construction equipment and tools. Compare to conventional rural housing based on brick and concrete, it has lower cost, better thermal and acoustic performance, shorter construction time, balanced indoor humidity and adequate waterproofing, durability, earthquake-resistant performance, lighting and ventilation. The do-it-yourself mode gives the homeowners freedom to build and promote the construction of mutual-aid community culture.

Wu Zhi Qiao Charitable Foundation and architect Mu Jun have initiated many demonstration projects in rural China. Education and training provided by them benefit to overcome the prejudice to rammed earth construction. Based on long-term funding, media publication and support of government and grassroots, modern rammed earth construction is spreading in China.

Village Activity Center in Maan Qiao Village is an attempt of long-span public rammed earth building. Its success proved that modern rammed earth construction will have broad development in China.

9 Modern bamboo architecture

Dr. HAO Lin is Managing Director of INTEGER Intelligent & Green, Director at Oval Partnership, Co-founder of Rural Community Development Group.

Lin has worked with a top international client on sustainable projects. Projects led by Lin include Sino-Ocean Taikoo Li Chengdu, Innhouse eco hotel Kunming, Melco International's Hengqin Island master planning, Hangzhou Intime City urban design, KPMG -CCTF community center in Sichuan, a pilot bamboo house in Kunming, and sustainability expert panel evaluation of URA project in HK.

In the influence of world's population booming and the social consumption surging, the precious rainforest is decreasing in the velocity of 12 million hm² per year. In daily life, we are more and more keenly aware of the harm brought by the greenhouse effect and air pollution. When we conceive the society in the future, environmental protection and sustainable development would become the indispensable elements. The 21st century will probably be the times in which we rethink the value and pattern of consumer society. Their work involves the effective use of the bamboo material resource.

Sustainability

Bamboo is environmentally friendly which meet the global demand for sustainability. It can be proved from six aspects as follows.

1. Bamboo is the fastest growing woody plant on this planet. Some species can grow 1 meter per day. One can almost 'watch it grow'. Bamboo in Southeast Asian can grow 10m per week. Its growth circle ranges from 3 to 5 years compared to a 20-25 year renew rate for timber. Bamboo yields measured in lbs/acre are four times that of wood. (Van der Lugt, van den Dobbelsteen and Janssen, 2006)

2. There is rich bamboo resource in China. Hunan, Jiangxi, Anhui, Zhejiang, Fujian, these provinces in China have more than a hundred Mu (Chinese unit of area, 1 Mu=666.667m²) of bamboo forest on average. We could use the bamboo resource to replace precious timber resource.

3. Bamboo forest is a carbon sink. Carbon sequestration properties of bamboo forest have been studied in China. The amount of carbon stored per year per hectare of bamboo forest is 0.59 Tons, which is 1.46 times that of fir forest and 1.33 times that of the rainforest. The carbon stored amount of bamboo forest is 11% of all the forest in China.

4. Bamboo has low embodied energy, which is 1/8 that of concrete and 1/50 that of steel.

5. Bamboo can conserve soil and water and sequester dust and exhaust gas. The amount of water conserved per hectare of bamboo forest is 1000 tons. The amount of dust absorbed per year per hectare of bamboo forest is 900 tons. A bamboo forest of 30,000 hm² sequester exhaust gas up to 38.6 million tons per year.

6. The bamboo forest has 150,000-200,000 per cm³ of negative oxygen ions. Ordinary forest has 100,000-150,000 per cm³. Urban neighborhoods have 1000 per cm³. Dense residence has 50 per cm³. Negative oxygen ions have health benefits.

Material properties

Table 5 Allowable stresses comparison between raw bamboo and various wood species (Becker, 2016)

Allowable Stresses (psi)

Species	Bending F _b	Tension F _t	Shear F _v	Compression parallel to grain F _c	Modulus of Elasticity E
Raw Bamboo ¹	3,450	4,070	313	1,270	1,560,000 - 2,070,000
Douglas-Fir Larch ² dimension lumber Select Structural	1,500	1,000	180	1,700	1,900,000
Douglas-Fir Larch ² dimension lumber No. 2	900	575	180	1,350	1,600,000
Douglas-Fir Larch ² dimension lumber construction grade	1,000	650	180	1,650	1,500,000
Southern Pine ² 2X4 Dense Select Structural	3,050	1,650	175	2,250	1,900,000
Southern Pine ² 2X4 No. 2	1,500	825	175	1,650	1,600,000
Southern Pine ² 2X4 construction grade	1,100	625	175	1,800	1,500,000

sources:

1 Janssen 1991

2 American Wood Council 2005

Bamboo has significant advantages in its structural properties when compared to timber. As shown in Table 5 and Table 6, all Allowable Stresses except for Compression parallel to the grain are greater for raw bamboo than those of most wood species. This information indicates that raw

bamboo poles are a good material for beams, but not necessarily for columns or other compression members such a top struts in a horizontal truss. (Becker, 2016)

Table 6 The comparison between Japanese bamboo and timber (Hao, 2010)

Species	Density (g/cm ³)	Compression strength (Kg/cm ²)	Tensile Strength (Kg/cm ²)	Bending strength (Kg/cm ²)	Fracture strength (Kg/cm ²)	Bending coefficient (10Kg/cm ²)
Moso Bamboo	0.63	780	1760	1400	170	125
Cedar	0.44	400	1200	750	75	90

Bamboo has been used as a structural material for centuries. Traditionally, the bamboo pole is used intact and tethered to adjacent poles to create a structure. Mechanical connections are difficult because of the hollow cylindrical shape of the bamboo pole and because of the variability of pole diameters and wall thicknesses.

If bamboo is laminated to form structural components, the material properties become significantly better than those of laminated wood, as shown in Table 7. (Becker, 2016)

Table 7 Allowable stresses comparison between laminated bamboo and laminated wood

Allowable Stresses (psi)

Species	Bending Fb	Tension Ft	Shear Fv	Compression parallel to grain Fc	Modulus of Elasticity E
Laminated Bamboo ¹	12,800	21,465 - 55,594	2,901	13,488	2,900,000
Laminated Bamboo ²	16,104	13,764	1,307	8,659	
Laminated Southern Pine 30F-E2 used primarily in bending	2,400	1,350	300	1,750	2,100,000
Laminated Southern Pine 50SPN1D14 primarily in compression	2,300	1,550	260	2,300	1,900,000

sources:

1 Lamboo Inc. 2011

2 Correal 2010

The material properties of Chinese reconstituted bamboo are better than those of wood, as shown in Table 8.

Table 8 The comparison between Chinese reconstituted bamboo and various wood species (WA and Hao, 2013)

Performance	Coefficient of Shrinkage (%)	Tensile Strength (MPa)	Flexural Strength (MPa)	Compression Strength (MPa)	Fire Rating	Formaldehyde Emission (mg/m ³)
Reconstituted bamboo	0.255	324	364	194	B1	0.1
Cedar	0.459	98.1	65.3	32.8		
Oak	0.392	153.55	110.03	62.23		

Laminated bamboo manufacturing process

The challenges for laminated bamboo manufacturing process are as follows.

1. Moisture and dimensional stability, waterproofing and fireproofing can be solved by normal precaution as done for laminated wood. It has been proved that laminated bamboo is more dimensionally stable than laminated wood products. (Nugroho and Ando, 2001), Unlike timber, the large amounts of starch present in bamboo makes it highly attractive to mold and fungi, termites and powder-post beetles. They cause much damage during drying, storage, and subsequent use. Tests have also shown that bamboo is more prone to soft rot and white rot attack than to brown rot. Appropriate treatment method can be used to protect bamboo from such degradation.

2. Adhesives do not bond well to bamboo without adequate surface treatment. The natural wax must be chemically removed or preferably scrapped from the culms. The only challenge to this problem is one of the economy. Any additional step in the lamination process requires more labor. Bamboo's cost is competitive in its natural form but significantly more expensive than alternatives in its processed form. (Mahdavi, 2011)

3. Construction and engineering professionals around the world are not yet adequately familiar with modern bamboo structure design and Formal codes and standards have not yet been developed. There is a stigma associated with bamboo. It is considered a construction material of the indigent. The reason is that in many areas of rural China where most bamboos grow, a lot of bamboos used for structural purposes in rural housing are untreated or not treated well and deteriorate in just a couple of years. Because not all traditional curing methods ensure satisfying results which leads to uncertainties about the advantages of using bamboo altogether. (Schröder, 2014)

In Chinese cities, bamboo construction is shunned in favor of reinforced concrete construction. In China, many designers have not been introduced to bamboo as a building material during their architecture education and are baffled by the lack of building codes in existence to direct its use.

Despite these challenges, laminated bamboo can be a practical structural solution in many design

applications. (Becker, 2016)

Local industrial development

The use of laminated bamboo as the primary building material allows for the growth of local industries in the planting, harvesting, processing and laminating of the bamboo. Growing, harvesting and laminating bamboo can all occur in places that lack infrastructure. The lamination process involves slicing the culms, removing the natural wax coating, treating and drying the pieces, gluing the pieces together and cutting or planning to the final shape. All of the steps can be accomplished without the use of electricity by using clamps or counter-weights for applying pressure to the bamboo strips after gluing (Mahdavi, 2011) These industries can alleviate the housing shortages at present and provide an export commodity to a nearby place with similar housing needs in the future.

The cost of laminated bamboo

The cost of laminated bamboo can be economic in areas with limited timber resources and low labor rates.

9.1 Application of Laminated Bamboo in Integer Bamboo House

Integer Bamboo House is the world's first home to be built from engineered bamboo products. It is designed and built by The Oval Partnership, is located at the Expo INTEGER Site in Kunming, Yunnan Province, China. Lightweight, durable and made completely from eco-friendly, renewable materials, the two-story home is an experiment in bamboo construction and was designed for the hilly terrain of the western part of China.

The reason why bamboo is used is that the area has abundant bamboo resource. Bamboo structure is light and, as a result, more effective in resisting earthquake than heavy concrete structure. The bamboo house can be constructed by local villagers without the need for heavy and expensive construction equipment. The technology used in the Kunming INTEGER bamboo house is based on a rain screen system and sandwich panels which provide very high thermal insulation value. The potential of this technology is immense. It can provide an affordable and ecological way of building for the new townships and villages in China.

The Oval Partnership carries out this action research and technology transfer project with the scientists and engineers from the local academic institutions, including the Kunming University of Science and Technology (KUST). (Hao, 2012a)

Structure

The house is platform framing (light-frame construction). The glued laminated bamboo pieces

dimension is 0.05m×0.10m (2 by 4 inches) at the cross-section. The scientists of KUST detected the tensile, compressive and torsional strength of glued-laminated bamboo sample with destructive testing. Then the engineers calculated the bamboo piece dimension accurately and designed stainless steel connectors according to Canada wood building code. The laminated bamboo pieces are connected together with nails or screws and stainless steel connectors. The builders pre-drilled the laminated bamboo pieces before screwing or nailing, in order to prevent them from splitting. The house has better load-carrying capacity and seismic wind resistance than a light-frame wood house.

Do-it-yourself construction

Unlike heavy timber or brick masonry, the light-frame construction does not require a special set of skills acquired after years of practice. It conforms to the do-it-yourself tradition of Chinese rural homeowners.

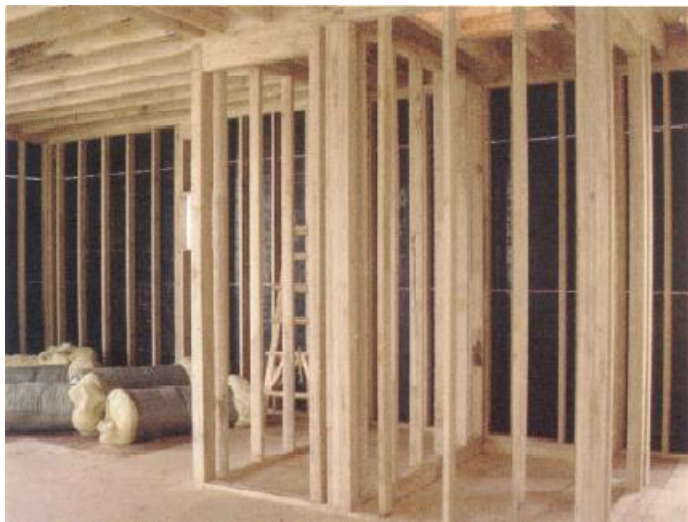


Figure 150 Partial Bamboo framing (Hao, 2009)

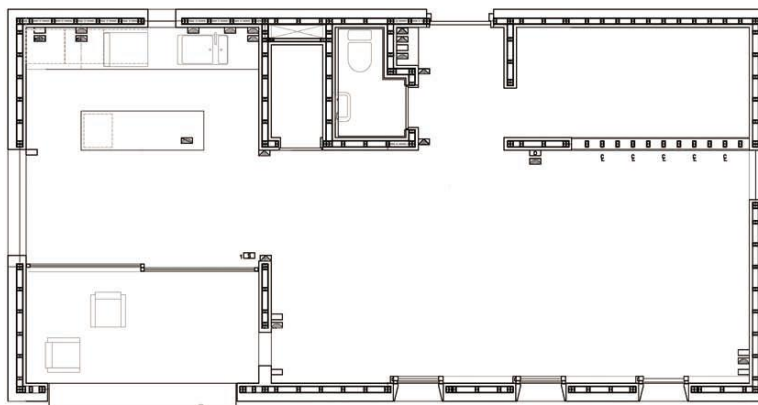


Figure 151 Plan (Hao, 2010)

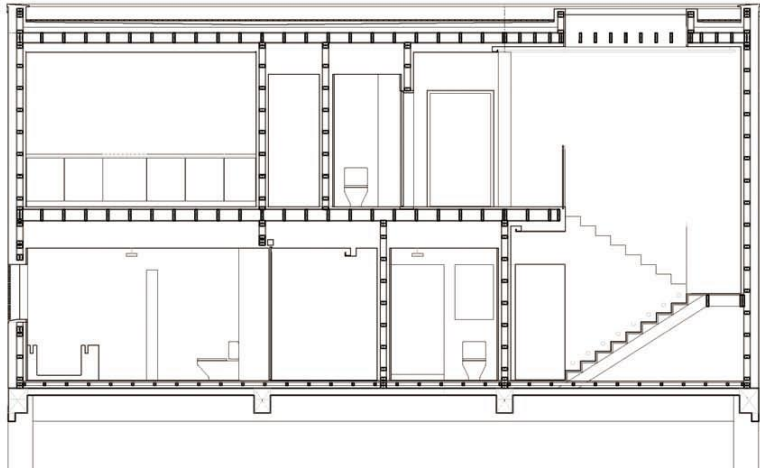


Figure 152 Section (Hao, 2010)



Figure 153 (left) Integer Bamboo House being built (Hao, 2013a)



Figure 154 (right) the entrance of Integer Bamboo House (Hao, 2013a)

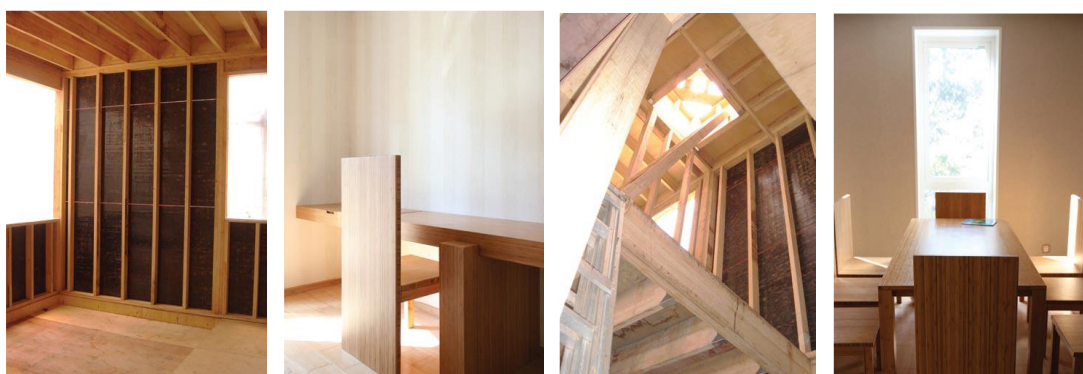


Figure 155 interior of Integer Bamboo House (The Oval Partnership, 2011)

The interior decoration and furniture are made of laminated bamboo. The bamboo furniture was designed by The Oval Partnership and manufactured by DASSO.

The construction cost of Integer Bamboo House is less than that of conventional reinforced concrete frame construction.

9.2 KPMG-CCTF Community Centre, Cifeng Village, Sichuan

KPMG China, in partnership with the China Children and Teenagers' Fund (CCTF) and Chengdu Women's Federation, on a pro bono basis, have built an exemplary green community centre in the Sichuan village of Cifeng as part of efforts to renovate the earthquake-devastated and poor region while promoting the development of the local rural communities.

Integer China proposes this center as a “community memorial hall”, which serves local community as a place where can bring blessing, inspiration, warmth, enlightenment, wellness and happiness.

The center is also a demonstration project for technology transfer of the area. The green innovations include long-span reconstituted bamboo structure (错误!未找到引用源。), straw bale wall, agricultural fiber board (Figure 156), biogas, reed bed filtration systems, green turf, etc.

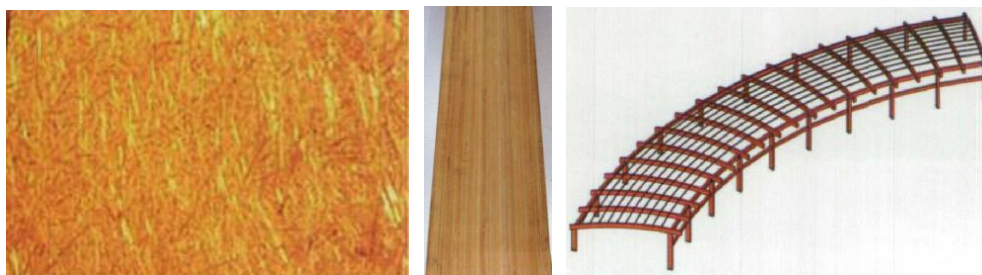


Figure 156 Agricultural Fiber Board (left), Laminated bamboo Lumber (middle), Long-span Reconstituted bamboo structure (*World Architecture Review*, 2009)

By creating connections within and beyond this site, by establishing a flexible mix of uses such as education, entertainment, professional training, sustainability exhibition, by adopting local and international expertise through partnership, by maximizing the natural of the site, by designing and constructing through social participation, the architect aim to create an ecological, pleasant, healthy and vibrant center. It is a demonstration scheme for rural sustainability.

The architect Hao Lin has made full use of locally sourced innovative materials and passive systems of environmental conditioning, building a people-oriented, energy-saving, and environmentally sustainable village. The building's post & beam structural material is reconstituted bamboo prefabricated and sourced from a local factory and sustainable forest. Pollution free straw fiber panels and laminated bamboo are used for the building envelope and floor finish.

This low budget philanthropy project has received pro bono manpower, resources and financial support from a partnership of 30 international and domestic green enterprises, research institutions and government agencies.

The 450 square meter Community Centre was opened on 17 May 2010, and is used for the extracurricular activities of local children and villagers' vocational training. The project has advanced sustainable rural community development by means of corporate sponsorship, public participation, and public-private partnership, and will serve as a paragon for improving sustainable construction, educational, cultural and recreational facilities in rural communities.

Credits and Data

Client: China Children and Teenagers' Fund (CCTF), KPMG China

Principal Architect: Dr. HAO Lin

Design Team: Peaker Chu, Takeuchi Hideaki

Key Pro bono Contributors: CEIC (Chengdu)/Solatube Daylight Technology, Co., Ltd., Dasso, Jialan Co., Ltd., Shaanxi Global board Industry Jiahe Co., Ltd. / Panel board Holding, China Southwest Architectural Design, and Research Institute, Beijing Tang Landscape Plan & Design Center

Size: 450 m²

Structure: Reconstituted bamboo

Cladding: Reconstituted bamboo

Interior: Straw fiber board

Design: 2008 - 2010

Construction: 2009 - 2010

Award: Design for Asia Awards 2010, best of the best of Perspective Awards 2010, China Children Charity Award 2011



Figure 157 North side of KPMG center, integrate with the rural landscape (Hao, 2013a)



Figure 158 new crescent shape architecture working with the function and passive design strategy (Hao, 2013a)

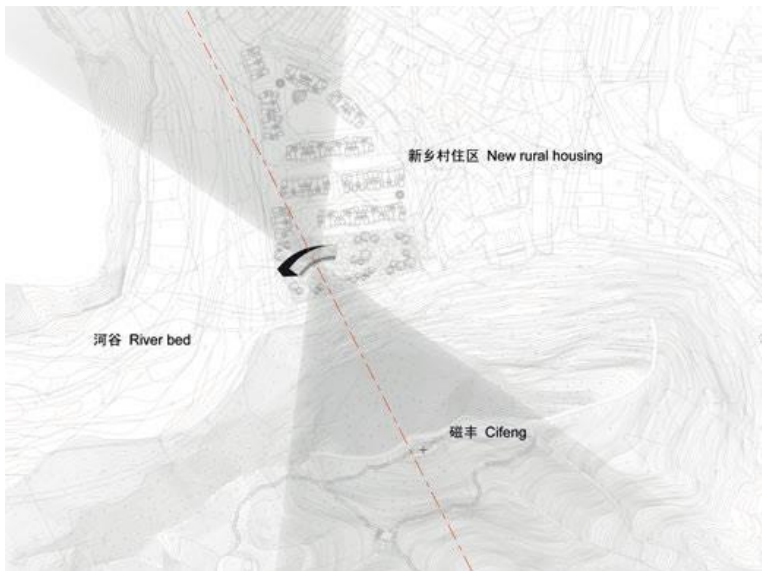


Figure 159 Site plan (Hao, 2013a)

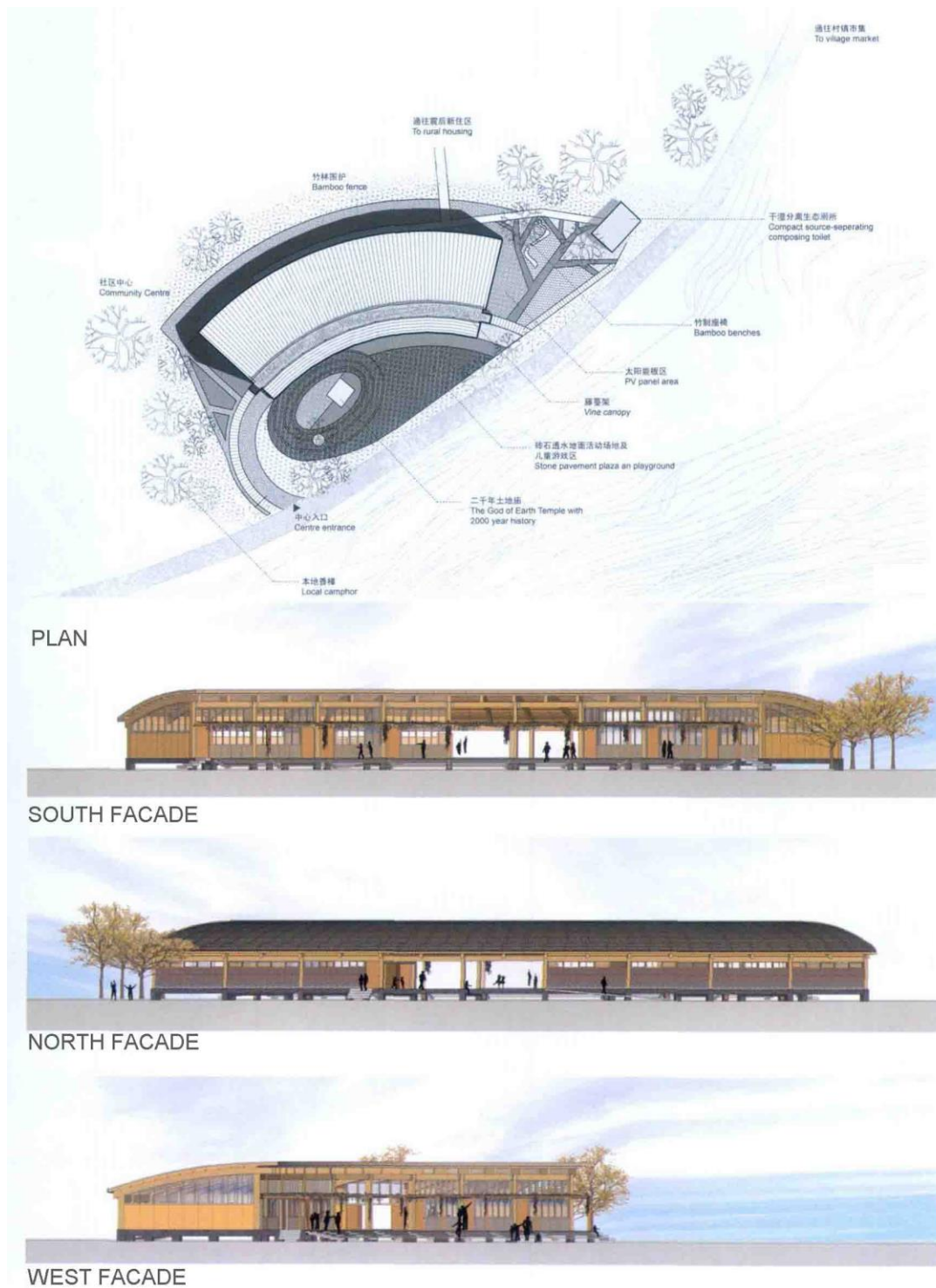


Figure 160 Plan and facades (Hao and Oval Partnership, 2012)

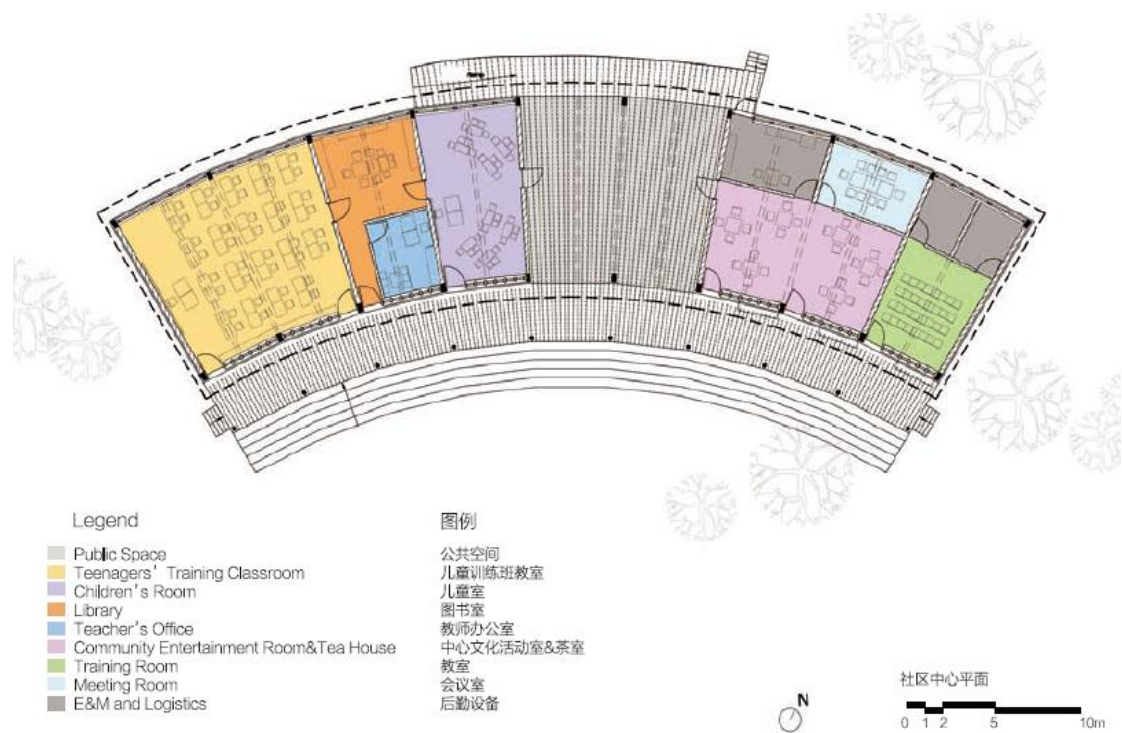


Figure 161 Plan (Hao, 2013a)

The function of the community center includes education (kindergarten, primary school, and technical training center), medical center and village activity center.



Figure 162 Post & beam bamboo structure construction (Hao, 2013a)

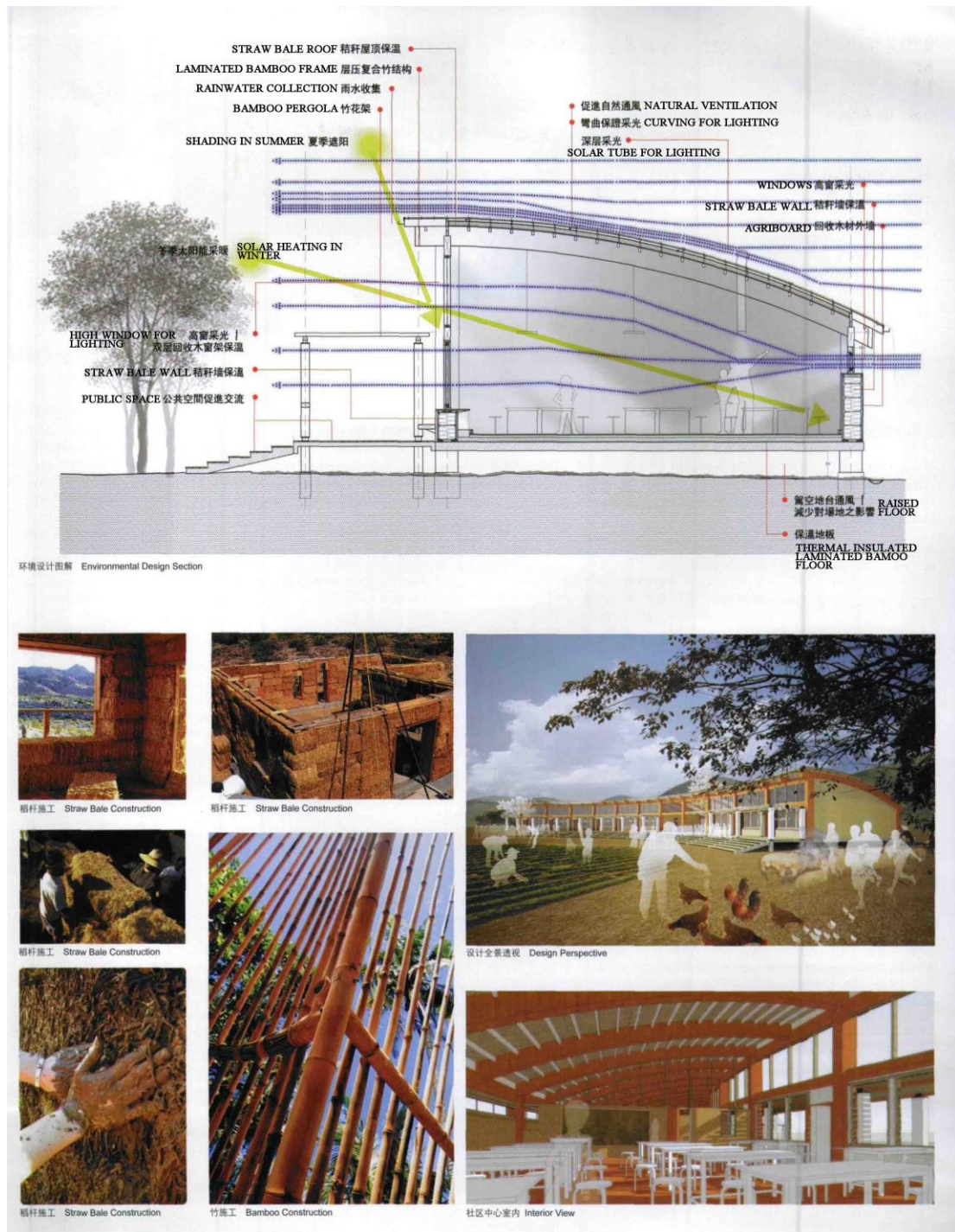


Figure 163 Environmental Design Section, straw bale and bamboo construction, design perspective and interior review (*World Architecture Review*, 2009)



Figure 164 Semi-open space encouraging village public life (Hao, 2013a)



Figure 165 The semi-open space and porch (Hao, 2013a)



1



2



3



4



5

Figure 166

1 solar tube for lighting

2 Village artist participating the community construction

3 Bamboo post & beam system and high-level window for natural ventilation and daylighting at the north

4 CCTF training classroom

5 Rural plaza and the village god temple (Hao, 2013a)

The project highlights a series of passive designs

With funds, services and volunteer effort, the assisting companies, individuals and charitable foundations worked together to develop environmentally friendly community in the less developed area. Passive designs were used to improve indoor environmental quality (IEQ) and achieve a low carbon scheme.

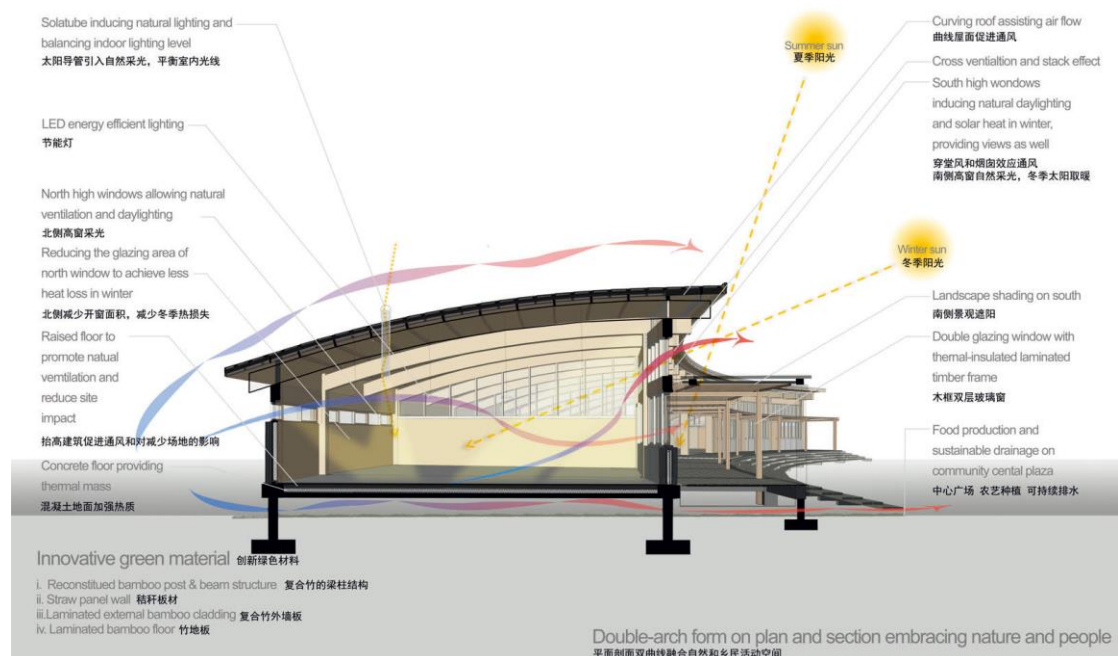


Figure 167 Passive design Diagram (Hao, 2013a)

New crescent shape architecture of gracefully curving single story structure captures the varying hourly and seasonal angles of the sun and air flow effectively, so that additional heating, cooling, and lighting are nearly unnecessary. The passive designs are as follows:

- Best southeast orientation
- In summer sunlight shaded out of the building by south high eaves, in winter sunlight penetrating into heart of building through high window
- Solar tube on the roof brings in natural lighting and improve indoor lighting
Solar tubes are affordable, high-performance lighting solutions that bring daylight into interior spaces where traditional skylights and windows simply can't reach. They have become the ideal solution for lighting interiors in a cost-effective, energy-efficient and eco-friendly way because they significantly reduce the need for electricity while keeping people connected to the outdoor environment. They are modular and easy to connect to ceiling systems. And unlike traditional skylights, they are designed to control the problematic aspects of sunlight. They reduce glare and inconsistent light patterns. They also screen infrared rays that can overheat interiors as well as ultraviolet rays that can fade furniture and fabrics. (CDATA, 2015)
- The bamboo pergola for shading in the south side
- The curving roof guide prevailing north wind
- North high window allowing natural cross-ventilation and lighting
- Raised floor promoting natural ventilation and reducing site impact
- Highly insulated straw bale walls and roof
- Double glazing window with thermal-insulated laminated timber frame
- Concrete floor providing thermal mass
- Rainwater collection system

Innovated green building materials to reduce carbon emission, waste and indoor pollution

- Reconstituted bamboo structure harvested and prefabricated from local sustainable forest and factory. It has been proved that the bamboo products used in the project are CO2 neutral due to the fact that bamboo is an important and very fast CO2 'fixator'.
- Formaldehyde free agricultural straw fiber panel for wall and ceiling cladding.
- Reconstituted bamboo for flooring.
- Recycled reconstituted timber for window frame
- Highly thermal insulated straw bale wall and roof

Other green & intelligent features

- Advanced communication connectivity and intelligent facilities for rural education
- Integrate a 2000 years old " the God of Earth Temple" within the design

- Bamboo mortise-tenon joint structure for robust seismic performance
- Energy efficient measures such as LED lighting
- Local rural training such as eco farm and green lifestyle
- Native species planting and sustainable drainage for irrigation.

(Hao and Oval Partnership, 2012)

Anti-seismic performance

The Laminated bamboo frame is lighter than reinforced concrete frame, so it has better seismic performance.

The joints of bamboo members are tenon and mortise. Mortise-tenon joints can decrease the story drift in small earthquakes and enhance the deformation restoring capability of framing in strong earthquakes.

The walls are built with straw bales. Straw bale structures have survived well in earthquakes worldwide. Structural engineering tests show straw bale walls have both good compressive and lateral strength and good ductile qualities.

Laminated bamboo Lumber Components

Integer developed the long-span reconstituted bamboo frame structure for KPMG-CCTF community center. The 240mm×450mm×12m curved main beams are the members with the longest span in the frame.

The construction used 20,000 Moso bamboo which had grown for 4 to 5 years. The processing includes cooking, carbonization, drying, reconditioning, sorting by color, finger jointing, hot (cold) splicing, buffing, fire retardant procession, damp treatment, etc. All the processing was done in the township enterprises.

The main drawback of finger-jointed laminated bamboo is the flexural capacity of poor, vulnerable to cracking. In order to increase the ultimate load-bearing capacity of finger-jointed laminated bamboo beams under flexure, the bamboo slice is 2 times thicker at the finger joint point.

Social consequence

Building a public building can provide exposure for a sustainable technique. The villagers who had witnessed the construction of the large laminated bamboo building. They had experienced laminated bamboo construction on a large, nice building without any risk to themselves. The builders who trained on KPMG-CCTF Community Centre could go home and build small, simple

laminated bamboo houses for themselves. It is benefits to the long-term technology transfer of the area.

Economic consequence

The project benefits to develop local bamboo industry, establish a business relationship, community and technology transfer for sustainable construction. The project also expanded to the improvement of infrastructure, living standard, health condition, women's and children's right, environmental protection and education. It is helpful to development and reformation of the rural economic model, lifestyle and building culture. Therefore, although KMPG Community Center is a micro-level village building, its social value orientation is humanization, sustainability, and empowerment scheme. According to the report, in the national top 10 counties with bamboo industry, the farmers' average net income from bamboo industry is about one thousand yuan per year; while Cifeng village's finance income from bamboo industry is about one millions yuan that occupies 50% of total finance income. Bamboo industry has become the pillar industry in Cifeng Village. If the bamboo industry could cooperate with the research institute and creative industry, it would have more economic value.

Role of architects

There is not any fixed mode sustainable construction. The architects worked together with the local people to adapt the advanced building techniques to the local conditions. They didn't stick to any conception like functionalism and modernism but struggled for people's well-being and long-term technology transfer.

Engineered Bamboo Production in China

Engineered bamboo is a low-cost product manufactured from bamboo. It is designed to be a replacement for wood or engineered wood but is used only when high load bearing strength is not required because building standards for this type of use have not been agreed by regulatory bodies. Engineered bamboo comes in several different forms, including bamboo scrimber and laminated bamboo, which has three times the structural capacity as normal timber and is defined and regulated by the ASTM International Standards. Engineered bamboo has been used as lightweight building construction (i.e., Integer Bamboo House) and large-scale public building (i.e., KPMG-CCTF Community Center) in China. In comparison to the woods that have been traditionally used, a number of benefits and drawbacks have been identified such as lower cost, greater hardness and shape retention, especially in high temperatures. (*Engineered bamboo*, 2016)

Engineered Bamboo is difficult to manufacture or market in China due primarily to a lack of a cost-effective processing technique and the fact that, to a great extent, structural board and structural dimensional lumber are products that have been deemed incompatible with the cultures in localities where bamboo growth is indigenous. In China, structural building materials have primarily been made from clay and cement block, reinforced concrete or, for bigger- budget

projects, steel. Value-added bamboo products are generally used for decorative purposes.

Our country is beginning to realize that we cannot solve twenty-first-century housing shortages with eighteenth century (and older) technology: i.e., brick and mortar. Currently, engineered bamboo manufacturing plants are being set up in several provinces. Many technologists recognize that most strains of bamboo, when processed into panels, yield a product of higher Internal Bond, Modulus of Rupture, and Modulus of Elasticity than the structural boards currently manufactured from soft woods. With the innovation of adding cost-efficient technology, bamboo suitable for engineered bamboo production are poised to have a significant impact on the next generation of structural building material for sustainable development. (Pasha and Abdulmalik, 2006) Except for the cost, the barriers to using include lack of recognition by building codes and experts in the manufacturing and construction. The bamboo constructions of Integer Intelligent & Green and Oval Partnership benefit to the process of drawing up Chinese bamboo building code and standard. In 2012, 'Sichuan Anti-seismic Bamboo Building Code' has passed the examination. (Sun, 2012)

9.3 Conclusions

The Integer Bamboo House in Kunming is the first multi-story laminated bamboo house in the world. KPMG-CCTF Community Centre is Hao Lin's first practice of long-span bamboo public building in the rural area. In Integer Bamboo House is DIY platform framing built with 2-by-4 laminated bamboo lumber. KPMG-CCTF Community Centre is post and beam frame with mortise and tenon joints.

Structurally and environmentally, laminated bamboo lumber (LBL) makes sense on dwelling and large-scale construction. The barriers to using include lack of recognition by building codes and experts in the manufacturing and construction, and cost. For example, in the project KPMG-CCTF Community Centre, we had to invite a Japanese bamboo specialist to design and supervise the laminated bamboo processing. Bamboo's cost is competitive in its natural form but significantly more expensive than alternatives in its processed form. The problem is that LBL beams today are in limited use. Manufacturers of LBL do not have the economy of scale to reduce prices. From an initial cost perspective, Laminated Bamboo Lumber will become more competitive with steel if demand for LBL structures rises. In China, the cost of LBL could be reduced by promoting bamboo housing and products. The demonstration bamboo building is the first step to test the application of LBL. Then we can promote bamboo construction through community involvement, education and training. When there were enough examples well tested and monitored, the bamboo building codes can be established, technology transfer and mass production will follow and the cost will reduce.

In recent years, Chinese bamboo industry set sail at full speed, and gradually expand the industrial scale, bamboo processing, and utilization management to make significant progress, bamboo industrialization process has accelerated noticeably. Bamboo materials were successfully introduced to the areas where there is no tradition of using bamboo. China has exported bamboo veneer for international projects such as the RIBA award winner New Area Terminal, Barajas Airport in Spain. There are over 100 species of bamboo currently being used by Chinese manufacturers of furniture, artifacts and bamboo plywood and LBL. Reconstituted bamboo framing construction has become affordable and ecological for rural residents in some areas. 'Sichuan Anti-seismic Bamboo Building Code' has passed the examination. (Sun, 2012)

Meanwhile, the bamboo forestry and industry drive the creation of businesses and markets for construction, fencing, furniture, household items, charcoal fuel, pulp, and paper, and speed up the development of rural economy and transfer of rural labor force. Reconstituted bamboo industry provides an innovative and sustainable empowerment scheme for rural builders.

10 Hsieh Ying-chun and Santiago Cirugeda's architecture practices

Hsieh Ying-Chun is a pioneer Taiwanese architect and contractor who has deployed his talents in rural areas for over a decade. He made the most effective contribution to the reconstruction through his exceptional professional skill and social engagement. In his socially engaged work, Hsieh and his Rural Architecture Studio had gained extensive experience over the previous nine years through their participation in grassroots community reconstruction in central Taiwan after the devastating 1999 earthquake. His reconstruction project for the Thao Tribe gained him international recognition. Hsieh organized the reconstruction of housing and communities in disaster-struck areas while faced with two challenges: to build houses within an extremely tight budget (25%-50% of the market price) and to base the projects on the notion of sustainable construction, green building, cultural preservation and creation of local employment opportunities. Hsieh has played a key role in rebuilding communities for Taiwan's tribal communities.

In more recent years, Hsieh has continued to help people build their own houses, from the remote villages of China to the sufferers of the South East Asian Tsunami.

When we face the future challenge of environmental crisis, a one-dimensional technical thought process is inadequate; the considerations must be broadened to cultural, economical, and environmental levels. (Hsieh Ying-chun, 2016) He constructed prototypical ecological farmhouses, assembly halls and toilets in China's Hebei and Henan Provinces in 2004-2006. Hsieh's team developed a building system (combining standardized light steel framing system and local infill materials) that can be built by residents, and which replaced the construction industry's slower and more expensive methods. Better adaptable to local customs, Hsieh's houses promote ecological sustainability by using materials with low embodied energy and techniques that reduce energy use. (Haddad and Rifkind, 2014)

10.1 Renovation of Traditional Chuandou Frame

10.1.1 Light steel frame

Inspired by traditional Chuan-dou timber frame, Hsieh Ying-chun simplified the light gauge steel construction. His light steel frame construction uses less steel.

Light gauge steel construction

Light gauge steel construction is very similar to wood light-frame construction (balloon and platform framing) in principle - the wooden framing members are replaced with thin steel sections. The steel sections used here are called *cold formed* sections, meaning that the sections are formed, or given shape at room temperature. Thin sheets of galvanized steel can be cold formed into steel studs for use as a structural or non-structural building material for both

with dry sheeting on both sides to form a load bearing wall. Construction with steel follows the platform frame system of house building. (*Light gauge steel construction*, n. d.)

Instead of wood plates bolted or nailed to the floor and ceiling or other top support, steel studs are attached to a galvanized steel channel of the same size and gauge as the studs. These channels are fastened to the floor with bolts, self-tapping self-drilling screws or self-threading concrete anchors, nails, or air-driven or powder-driver pins. (Havel, 2008)

Contractors will usually order pre-punched sections - sections with factory-made holes in them - so that wires and plumbing can be easily passed through the walls. The gaps between members are filled with insulation. (*Light gauge steel construction*, n. d.)

This form of construction can also be used for non-structural framings, such as interior partitions or external cladding. (*Light gauge steel construction*, n. d.)

Steel-frame walls can be assembled as units, tipped up, plumbed and leveled, and attached to the floor and top supports. The bottom and top channels can also be attached to the floor and ceiling, and the studs can be attached individually to them. Studs for load-bearing partitions will run from the floor deck to the underside of the floor or roof structure above. Fire-rated partitions will run from the floor deck to the underside of the floor or roof deck. The drywall board will be cut precisely to match the corrugations in the underside of the steel floor or roof deck. Studs for other walls will end a short distance above the level of the finished ceiling and will be braced against other walls or the floor or roof structure above for stability. Studs are connected to the top and bottom channels with self-drilling screws. (Havel, 2008) The spacing between studs is typically 16 inches on center for homes exterior and interior walls depending on designed loading requirements. In office suites the spacing is 24 inches on center for all walls except for elevator and staircase wells. (*Steel frame*, 2016)

Steel framing provides excellent design flexibility due to the high strength to weight ratio of steel, which allows it to span over a long distances, and also resist wind and earthquake loads. (*Steel frame*, 2016)

The Chuandou timber framing

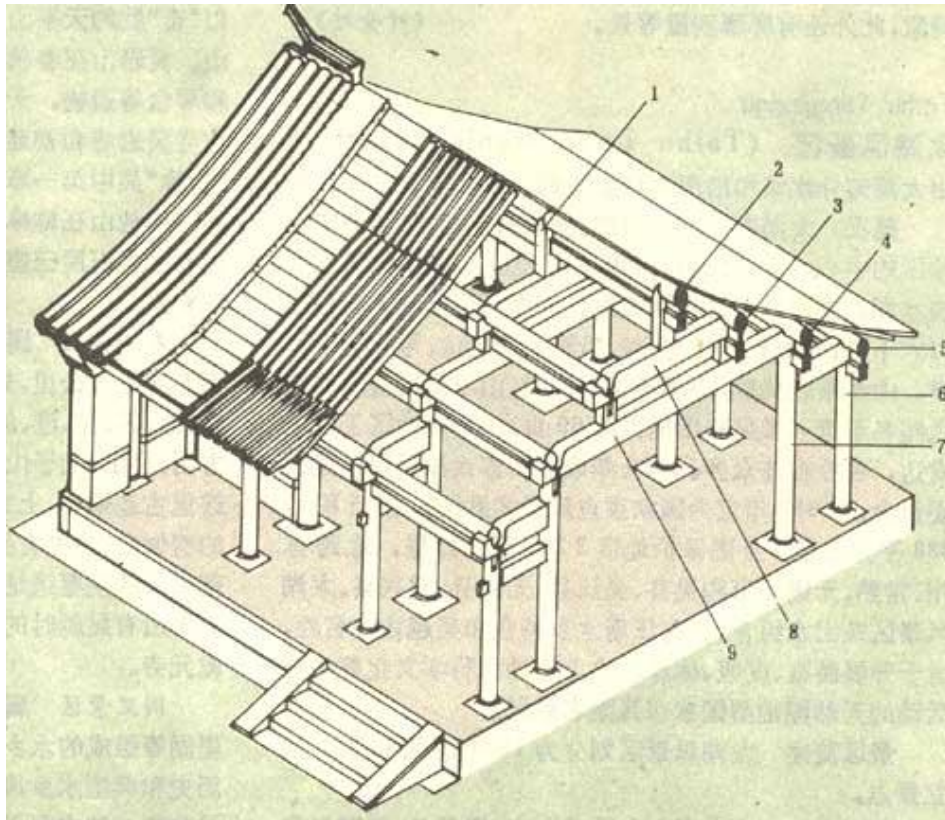


Figure 169 Chuandou Timber Framing (Chen, 2004)

Chuandou type is one of the Chinese traditional timber structures. It is usually used in the rural homes in the south of China. The homes have good seismic performance, which is mainly achieved by the frame deformation and friction slip.

This Chuandou timber framing system is mainly composed of beams which penetrate or cross the columns at different heights to assemble the framing system. The Chuandou means “penetrating through and then assembling together”, where the beams were penetrated through or mortised into the posts, and then put the purlins upon the top of the posts. The rows of columns are set according to the amount of the purlins in the direction of the depth; the purlins are set on the columns; the rafters are less important than in the light steel gauge frame, are for roof sheathing installation. The load on the roof transmits to the purlins and columns; beams connect each row of columns in the direction of the depth, forming the roof trusses; the purlins connect the roof trusses. The roof truss is always used for the gable ends and the partition walls. In some elaborate Chuan-dou frame, there are lintels set under the purlins to connect the roof trusses.

The lowest beam is the longest one made from two-single beams with a joint inside the middle post, the single beam extending directly through the front corner posts to form an overhanging eaves, and the other single beam through the back corner post made a rear overhanging eaves. Two kinds of joint have been found, that are the continuous type and non-continuous type

(dovetail connected type, flat cut type or double-tenon type as found so far).

Assembling

Typically, the head of all columns was cut in a curve to support the roof purlins.

No less than three short columns were set on the beams between two long columns with a distance between 120 and 280 centimeters, and the upper part of each short column should be penetrated by a beam and then put on another lower beam. In some cases, the beam is ended at the back long column and then uses another small beam at the lower position to form a passageway at the back. Those beams are both horizontal or with a curve shape, because the end of this beam has to be set under the roof purlin, so as to form a curve shape. To avoid for wasting wood materials, a piece of wood is cut into two pieces.

Framing on the ground

Chuandou timber frames are framed on the Ground. At the first, all components of forming a frame are put on the ground beside the location which the frame is being erected. Secondly, the long columns are put into their actual positions where they are erected. Thirdly, the beams are brought one by one to penetrate through different columns by a whole component or two components combined by the joint. The order of framing is the middle one at the beginning and the lowest one secondly, and then the other beams higher than the middle one are worked one by one from the bottom one gradually to the top one. Fourthly, the short columns are put on the beams higher than the middle one. Finally, the whole frame is put together

Raising the frame into place

The raising of a Chuandou timber frame can be done only by the traditional technique in using long poles or ropes. The whole frame already assembled can be carried by five or seven men and laid on the ground beside the place where they are erected. The master carpenter uses a long pole or rope nailed or tied on the top of the central column where the center of gravity is in the whole frame. By helping from his assistants, the whole frame is then raised up on the brick foundations and/or stone pedestals, or on the rammed floor only. Four long sticks are then nailed on the columns for the temporary fixings at the top, and fixed on the ground at the bottom. Finally, while another frame is raised later, lintels connecting these two frames are then set to joint them together to form a box-frame in the main hall. Following the same process, the other Chuandou timber frames located on other rooms are then gradually raised one by one, and then erected on the actual position at the end.

Finally, four people hoist up the ridge-pole and then Putting upon Two Frames. (Fion, Lin and Hsu, n. d.)

Hsieh Ying-chun's LGS frame



Figure 170 Hsieh Ying-chun's light steel frame construction (Wu, 2014)

In the light steel gauge frame, the studs will be more closely spaced to support the rafters. Inspired by Chuandou timber frame, the main load-bearing components are frames and purlins. The frames are made of columns and beams. The frames are connected by purlins. Therefore, the vertical load-bearing steel members and rafters in his light steel construction are fewer than in the light gauge steel frame.

The typical profiles used in Hsieh Ying-chun's light steel construction are the C-shape stud and the U-shaped track. The thickness of steel members are 3mm or 10mm.

The assembling process is similar with the Chuandou timber frame.



Figure 171 The builders were assembling the frame on the ground, 'Earth House 002' (Huang, 2007)

Framing on the ground (Figure 171)

Steel frames are framed on the Ground.

(1) At the first, all components of forming a frame are put on the ground beside the location which the frame is being erected.

(2) Secondly, the long columns are put into their actual positions where they are erected. The columns used in the frame are usually U-shaped 10-mm-thick steel. Column spacing is 1200mm or 1100mm.

(3) Thirdly, the beams combine columns by a whole component. Beams are 3-mm-thick steel. Connections between members are made with self-tapping self-drilling screws, bolted splice or welding. The bracings are used to strengthen the frame.

(4) Finally, the whole frame is put together.

In Chuandou timber framing, the concept of 'Jian' forms the order of the space. Space is divided into several 'Jian' by frames. The modular dimension of 'Jian' is the spacing between frames. Hsieh Ying-chun adopts the concept in his LGS framing whose modular dimensions are usually 3600mm or 3300mm.



Figure 172 Builders were raising the frame into place, reconstruction of Yangliu Village, Mao County, Sichuan Province (Hsieh and Atelier-3, 2015)

Raising the frame into place (Figure 172)

The raising of a Chuandou timber frame can be done only by the traditional technique of using long poles or ropes. The whole frame already assembled can be carried by five or seven men and laid on the ground beside the place where they are erected. The master carpenter uses a long pole or rope tied to the frame. The whole frame is then raised up on the concrete, brick and/or stone foundations or pedestal. Four long sticks are then fastened on the columns for the temporarily fixings at the top, and fixed on the ground at the bottom. Following the same process, the other steel frames are then gradually raised one by one, and then erected on the actual position at the end. Finally, purlins connect these frames together to form a box-frame.

The frames are then fastened to the pedestals or foundation with bolts, screws or self-threading concrete anchors, nails, or air-driven or powder-driver pins.

Connections between members

The connections between members are usually self-tapping self-drilling screws, bolted splice or welding. And there are various connectors being used.



Figure 173 (left) connection between column and beam (Wu, 2014: 75)



Figure 174 (right) connection between beams (Wu, 2014: 75)



Figure 175 (left) connection between column and bracing 1 (Wu, 2014: 75)



Figure 176 (right) connection between column and bracing 2 (Wu, 2014: 75)

Advantages of light gauge steel construction

Hsieh Ying-chun's light gauge steel structures have many of the advantages of light steel gauge framed structures:

- (1) They are light, and allow quick building without heavy tools or equipment. Every component can easily be carried by hand - a house is like a carpentry job on a larger scale. The main tool is a light, handheld screw gun. Since steel is strong, the structures are lighter than wood framed structures of equivalent strength.
- (2) Their higher strength allows greater spacing between members when compared to wood frame construction: about 24" (600mm) for light steel construction vs. about 16" or 20" (400 or 500mm) for wood. Fewer members translate to quicker construction times.
- (3) It is dry construction without the use of plaster or mortar. The use of dry materials speeds the construction process and allows earlier occupancy.

- (4) It is able to shape itself to any form, and can be clad and insulated with a wide range of materials.
- (5) It is easy to change or modify this construction at any point in its lifespan.
- (6) There is a great range of systems and products catering to this type of construction.
- (7) Light steel is non-combustible. Since steel loses its strength in fire quite easily, it must be protected from fire with fire rated sheeting.
- (8) Light steel does not rot, shrink, warp, or decompose like wood structures, and can be used in areas where there is a probability of termite attack.
- (9) Light steel is able to be recycled.
- (10) Compared to reinforced concrete and masonry construction, light steel construction has higher floor area usage.

Table 9 The comparison of floor area usage of various constructions (Wu, 2014: 71)

Structure system	Floor area (m2)	Usable floor area (m2)	Floor area usage
Brick masonry construction	360	262.8	73%
Reinforced concrete frame construction	360	282.24	78.4%
Straw bale and light steel framing	360	331.2	92%

Disadvantages of light gauge steel construction

Hsieh Ying-chun's light gauge steel structures have disadvantages of light steel gouge framed structures:

- (1) Light framed structures allow the passage of sound more readily than the more solid masonry construction.
- (2) Light gauge steel will lose strength in the advent of fire. Adequate fire protection must be used. The easiest form of fire protection is to clad the steel with fire rated sheeting or drywall.

(*Light gauge steel construction*, n. d.)

Comparison of balloon, platform and Hsieh Ying-chun's steel framing

Comparison of structural forms

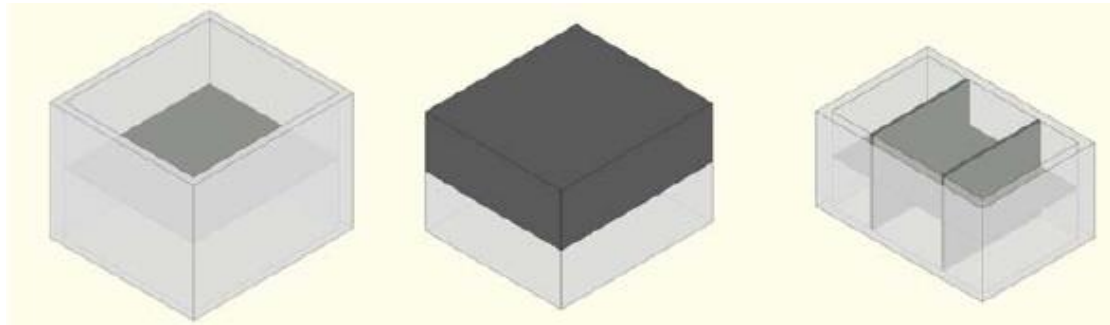


Figure 177 balloon framing (left), platform framing (middle), Hsieh's steel frame (right) (Jia, 2012)

Comparison of building orders

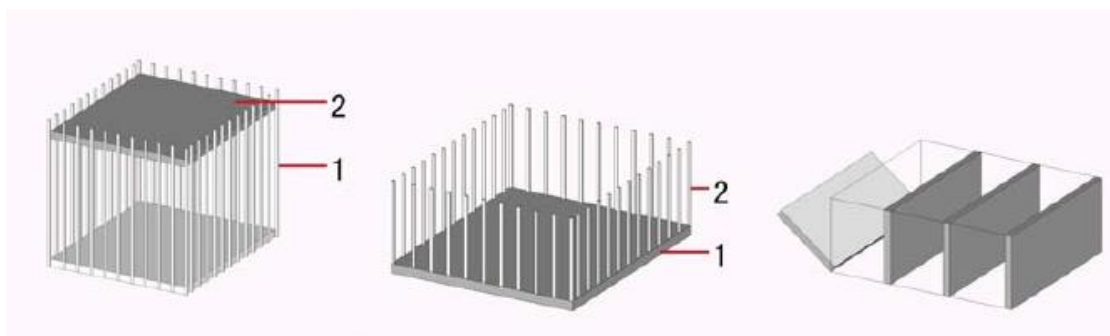


Figure 178 balloon framing (left), platform framing (middle), Hsieh's steel frame (right) (Jia, 2012)

As shown in Figure 177 and Figure 178: 1) Balloon framing is an integral box. Studs which run continuously from top to bottom of a building. The roof is a truss structure that consists of horizontal ceiling joists and sloping rafters. The vertical load-bearing members - studs are built first. 2) Platform framing is divided into multiple boxes by floors. The horizontal floors are built first. It utilizes plates to enable the upward extension of a building. Floor joists for each story are supported by the top plate of the floor underneath. The main difference from the balloon framing occurs at the floor lines. 3) Hsieh's LGS frame is divided into multiple boxes by vertical frames and horizontal floors. Beams, columns and floors cross each other. The vertical frames are built first. The main difference from the balloon framing occurs at the floor lines and the frame lines. It can be extended laterally. It is the open system interpreted by Hsieh.

Comparison of column-beam connections

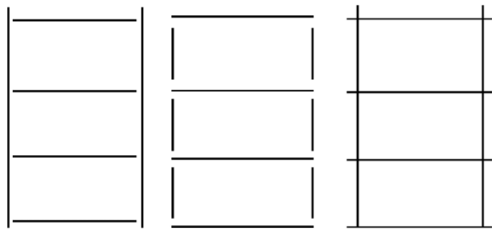


Figure 179 beam-column connection of balloon framing (left), beam-column connection of platform framing (middle), one of the possible beam-column connection of Hsieh Ying-chun's steel frame (right). (Jia, 2012)

Hsieh Ying-chun's steel frame can be the three forms shown in Figure 179. The beam-column connection of balloon framing is the form shown in the left image (Figure 179). The beam-column connection of platform framing is the form shown in the middle image (Figure 179).

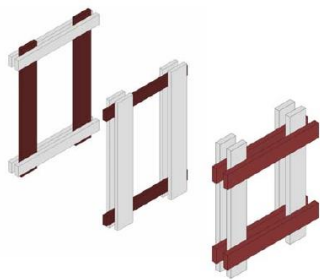


Figure 180 beam-column connection of Hsieh's steel frame (Jia, 2012)

In Chuandou timber frame, beams can penetrate through or mortised into the posts. Hsieh transplants this mode into his steel frame, and simplified the tenon and mortise joints into bolted connection, so beam and frame can cross each other as shown in Figure 180. Compared to tenon and mortise joints, bolted connections have better plastic deformation capacity.

Balloon framing Vs platform framing Vs Hsieh's LGS framing

Construction process

Platform framing is the simplest construction process. The technique involved also makes it the quickest method of construction. One frame is constructed and is well supported by a foundation. Builders then use the first level as a platform to project the next floor. The process continues until the desired number of floors is achieved. Rafters and roof joists are erected on the final tier of walls. The safety level for workers is highest with platform framing. This is because walls can be fabricated down on the floor. The technique also requires less labor. This helps to keep construction costs within reasonable limits.

Hsieh's LGS framing takes the second place in simplicity and speed of construction process.

Because beams, columns and floor joists cross each other, the bolted connections are more complicated than balloon and platform framing. The frame can be raised by 5 to 7 people, the long columns used in construction pushes up construction costs. After raising and fastening all the frames, builders build the second floor. Then they use the floor joists as a platform to erect purlins and roof joists.

The balloon framing construction process is the most difficult and slowest. The long framing members used in construction pushes up construction costs. Walls constructed turn out to be very heavy. To raise these walls, more labor, skill and specialized equipment is required. It also increases the risk during work.

Steel consumption

Hsieh's LGS framing utilizes the least steel. Because its members spacing is wider than balloon and platform framing.

Anti-seismic performance

Because of the multiple boxed-frames in horizontal and vertical directions, Hsieh's LGS frame has the highest deformation capacity. Thus, it has best anti-seismic performance. Platform framing comes second, balloon system follows.

Possibility of extension

Because the beams, columns, and floors can cross each other, Hsieh's steel frame is open, flexible and extendible. It can be extended laterally.

Platform framing can be extended upward.

Balloon framing cannot be extended.

Resilience and wind resistant

Balloon framing and Hsieh's steel frame have higher resilience due to the longer studs or columns used than platform framing.

The balloon framing building is best able to withstand high speed or gusty winds, Hsieh's LGS framing comes second, because of the partial longer members – columns in the frame are fastened to the foundation. Platform framing follows, since the studs are connected to the platforms except those of the ground floor.

Construction operation

The construction operation of Hsieh Ying-chun's LGS framing is similar to the traditional

Chuandou frame method, which is understandable for the villagers in the southern mountain area. Hsieh Ying-chun's LGS framing combined industrial production and low-technology. Connection pieces are bolts, rod and self-tapping screws to get rid of the welding procedure and sporadic work piece (offcuts which reduce construction accuracy, but do not support the structure), and to increase the strength of the structure.

Manufacturing

To facilitate the industrial manufacturing, the light steel of Hsieh's LGS framing is simplified to two types of sections and the connection pieces including bolts, rod and self-tapping screws are standardized.

After examination of the universal test machine, the special typed light steel and connection pieces are manufactured in the factory, which achieves the industrialization of housing. However, it is not suitable for popularization in some remote rural areas with a low level of industrialization in China at present.

10.1.2 Timber frame

Chuandou timber frame construction is very popular in Southern China. Based on it, Hsieh Ying-chun developed his timber frame construction.

Hsieh Ying-chun's "Earth House 001" is wood frame construction. The timbers are recycled from the construction and demolition waste or bought from the tree farm nearby. Hsieh Ying-chun has no experience of building with round timbers. So local carpenters squared the round timbers to meet Hsieh Ying-chun's requirement.



Figure 181 round timbers (left), square timber (right) (Wu, 2014: 74)

The local craftsmen made tenons and mortise with electric saw and drill, as shown in Figure 182.



Figure 182 Tenon (left), making mortise with electric drill (middle), three mortise (right)



Figure 183 the builders were assembling the frame on the ground. (Wu, 2014: 73)

Bracings are added into the frame. They provide stability and resists lateral loads. Columns, beams and bracings, all components of forming a frame are put on the ground beside the location which the frame is being erected, as shown in Figure 183.

Bracing is rare in Chinese traditional timber frame construction system.

Tenon-and-mortise Joints and bolted connections between timber members.

Hsieh Ying-chun uses tenon-and-mortise Joints and bolted connections in his timber frame constructions.



Figure 184 Tenon-and-mortise Joints (left) and bolted connections (right) (Wu, 2014: 76)

In projects of mainland China, Hsieh Ying-chun always uses tenon and mortise joints. Because these projects are located in the remote villages where there is not steel processing plant. The joints between beam and purlin is dovetail tenon and mortise. They are fixed with wooden pins.

Half the wooden pin is in the beam, the other half is in the purlin. (Figure 186)



Figure 185 (left) wood pins (Wu, 2014: 76)



Figure 186 (right) purlin and wood pin (Wu, 2014: 76)

10.1.3 Bamboo and steel mixed frame

Bamboo has good parallel-to-grain compressive and tensile strength. Raw bamboo is light and hollow material, is similar to U-shaped steel. Hsieh Ying-Chun designed a bamboo steel mixed frame, as shown in Figure 187. Its assembling process is similar with his light steel frame construction. The connections between bamboo and steel members can be tied together using traditional lashing knots or bolts. The bamboo and steel can be filled with cement to strengthen the structure.



Figure 187 bamboo steel mixed framework (Wu, 2014: 74)

10.2 Santiago Cirugeda, heavy-frame construction of H Timber Beam and removable steel frame

Santiago cirugeda uses a set of prefabricated building materials according to their physical properties and mechanical intrinsic, such as removable steel, H Timber Beam, Oriented Strand

Board, strand wood cement board, recycled shipping container, recycled aluminum alloy windows and doors. Removable heavy steel and H timber beam are used for the structural pieces of the frame. The heavy frame of the Grow School is a blend of removable steel and H Timber Beam. (Figure 188) The frame of Meditation Home is made of H Timber Beam. (Figure 195) He also uses local natural materials for decoration. For example, the exterior walls of Meditation Home are decorated with firewood. (Figure 194)



Figure 188 (left) The Grow School (La Escuela Crece), Escuela Superior De Diseño De Madrid (Author's own photographs)



Figure 189 (right) The Grow School (La Escuela Crece), Escuela Superior De Diseño De Madrid (Author's own photographs)



Figure 190 (left) heavy-steel frame of The Grow School (La Escuela Crece), Escuela Superior De Diseño De Madrid (Author's own photographs)



Figure 191 (right) Building materials of The Grow School, OSB, Wood Strand Cement Board, double T wood beam (La Escuela Crece), Escuela Superior De Diseño De Madrid (Author's own photographs)



Figure 192 (left) The roof of the Grow School (Author's own photographs)

Figure 193 (right) Detail of the Roof, The Grow School, Madrid (Author's own photographs)

The removable steel frame uses hot rolled steel. Its pieces are connected with bolts. Compared to the cold-formed steel for light steel frame, hot rolled steel sections tend to be thicker and more robust and tend to be used for larger span buildings. As too heavy, the hot rolled steel pieces tend to be hoisted by crane. For example, the roof of the Grow School as shown in Figure 192 have to be hoisted.

Cold rolled steel offers a high strength to weight ratio and is lightweight and easy to handle, making it perfect for use in modern construction. Cold rolled steel is particularly well suited for use in self-building prefabricated housing. Foundations for cold rolled steel buildings also tend to be more shallow and cost effective than for hot rolled steel buildings.

The structure of both hot rolled and cold formed buildings have to be designed by the engineer. Because cold rolling is carried out at room temperature, it can be achieved in small-scale village plant. The construction operations of light steel frame is much simpler than heavy steel frame, so it tends to rely less on construction supervision and hoisting crane.



Figure 194 Meditation Home of Dhamma Centre in Spain (Author's own photographs)



Figure 195 Meditation Home of Dhamma Centre in Spain (Author's own photographs)

The H Timber beam is entirely made of massive wood in a totally mechanized way. It is handy, strong and versatile. It can be used as primary beam, secondary beam and support. It is coated with yellow-color painting for waterproofing, rot-proofing and frozen-proofing. It has Indeformability, dimensional stability, lightness and handiness, high resistance to atmospheric agents, long durability thanks to high quality gluing, saving on time and cost of manufacturing, a large range of usages, easy disposability and protection from accidents thanks to round edges. Santiago connected the structural pieces of the Meditation Home with bolt or nail. So the construction is removable.

Compare to the Hsieh Ying-chun's timber frame, H Timber Beam is lighter, stronger, safer and more durable.

10.3 'Open' Construction System

For Hsieh Ying-Chun, the designing of details is an act of agency, since it 'represents a real opportunity to consider and intervene in some of the most basic social and environmental issues'. (Roan, 2007) He and his co-workers re-consider and re-look at commonly used construction techniques like LGS construction, timber and bamboo framing construction and adjust them so that they are cheaper and easier to use. Sometimes this is about simple things such as the replacing of welded constructions with screws, or of developing a system of construction that minimizes the use of high-tech patented connections that are extremely expensive. This enables a DIY, 'open-architecture' which does not require the need for specialized tools or knowledge, making it possible for those with little or no prior knowledge to participate fully. (*Spatial agency: Atelier-3 / rural architecture studio*, no date)

The vernacular ecological techniques and design philosophy of traditional Chinese dwellings conclude the aspects still valuable to be inherited nowadays.

Hsieh's "open" method involves "less architecture, more participants, and more ancestors." Less architecture means withdrawing the "domination" of the designer-architect and returning "ownership" of the design, labor and space allocation to the occupant by using "the simplest, the plainest building methods that are permeated with culture, society and community spirit," he says. "That is to void architecture, and yield the common project to man, spirit and nature as principal participants." Reflecting on this symbiosis, on the increased oneness with nature and on the growing awareness of our identity on and with the Earth, Hsieh sighs, explaining, "It is ironic that so-called advanced or sustainable ideas can only be invoked under the most destitute and impoverished conditions." (Stanley-Baker, 2009)

In one project, he helped the local community to set up a factory in their village which now produces prefabricated steel elements that can be sold to other communities that are also in

need of low-cost housing. (*Spatial agency: Atelier-3 / rural architecture studio*, no date)

Santiago's construction system is also open to all the people, he works as a coordinator. All the people can participate in the construction. The construction technique is very simple, everyone can learn it quickly. Sometimes, the builders can design the building in the construction. For example, in the Grow School project, the windows are designed by the builders in the construction process. He proposed to inherit the spirit of nomadic architecture: removable and transferable architecture and social architecture.

10.4 Relationship between architects and occupants: Inter-subjectivity

Inter-subjectivity is encouraged by Hsieh Ying-chun to deal with the relationship between the designers and occupants. After the architects set up an opening platform, the building workers and dwellers can participate in the construction progress, put forward design concepts from different perspectives and embody living conditions, cultural environment and religious beliefs through the residential.

For example, after the framing is established, local building culture can combine with it. Rural residents participate the construction through using their vernacular building techniques for infills and finishes.



Figure 196 Two members of the Ita Thao tribe use bamboo to roof their own house after training from Hsieh and his team. (Courtesy of Hsieh Ying-chun) (Stanley-Baker, 2009)



Figure 197 villagers built stone masonry using their traditional techniques. Yangliu Village, Mao County, Sichuan (Hsieh and Atelier-3, 2015)

Usually, rural construction led by Hsieh Ying-chun mainly includes the following three stages: First of all, preliminary preparation, Hsieh Ying-chun's team cooperates with the government, experts, scholars and contractors to solve the issues of raising funds, selecting construction land, calling for tenders of the project and so on. Residents' advice is not directly involved in this phase.

Secondly, design and production. the designer's team negotiates with the local government and the construction team of foundation during this period. After base research and project design, they help the government select housing types and build model houses. Because most of the villagers do not understand the blueprint, the designers explain their project to them by holding meetings and displaying design sketches.

Thirdly, collaborative construction. Hsieh Ying-chun's team partakes in assembling the labor force, instructing construction and safety supervision. The progress that the staff guides collaborative construction can be regarded as a continuous show. The architects strictly control the construction sequence and details, and help the locals build confidence. The villagers get command of the whole process by observing and imitating.

There is a great difference in the charge mode between Construction Solidarity and usual design fee, because the cost of design is included in the production of the light steel structure. The cost of the light steel structure is 700- 800 yuan/m² if the locals build houses all by themselves.

The process that unites modern architecture design, construction and operation with self-built housing demands both quasi-specialization of rural participants and differentiation of architects, which is different from conventional rural constructions. The architects are not only designers but also producers and distributors by optimizing light steel structure and building open system. At the meantime, the architects do not control the occupants' own needs, but allow them to reach their full potential and awaken their collective consciousness. (Dou, 2016)

10.5 Construction Solidarity

Hsieh Ying-chun argued that cooperative is a unique interpretation of sustainable development. Hsieh Ying-chun proposed Construction Solidarity - a cooperative housing mode. The construction technology simplification of the 'open' construction system can be viewed as the prerequisite of Construction Solidarity, which is reflected in its progress from focusing on the construction of the whole building to the production of the light steel components, from emphasizing eco-friendly material such as straw-clay to paying attention to the material that the natives familiar with.

Provided the building process is supervised by an experienced individual, rural residents can grasp the simple construction techniques quickly and practice their building culture reflecting living conditions, cultural environment and religious beliefs within the 'open' construction system. Under this mechanism, a semi-autonomous construction system responding to cultural diversity is formed and residents' community awareness is established during the construction process, which may be a possible solution for affordable and sustainable rural housing. (Dou, 2016)

The behavior of mobilizing neighbors to participate construction in agriculture society evolved into construction cooperative in industrial society, especially in rural areas. But in many remote villages in mainland China, the cooperative has not formed. Hsieh Ying-chun and his group attempt to develop cooperative in rural China.



Figure 198 construction cooperative (Huang, 2007)

'We wanted to encourage local people to join the reconstruction...The best therapy is activity. House-building takes a lot of energy as well as a lot of cooperation. Being involved in such an activity helps to eliminate the suffering caused by the disaster.' (Hsieh, 2011)

A cooperative ("coop") or co-operative ("co-op") is an autonomous association of people who voluntarily cooperate for their mutual social, economic, and cultural benefit.

Members of cooperatives are mostly from the socially vulnerable groups. They survive and develop in the fierce social competition with the unifying power, and they solve the economic problem which can't solve with individual power in the production and life in the form of mutual assistance.

Cooperatives play an increasingly important role in economic development when facing the challenges from economic globalization. People in most of the countries and regions in the world enjoy the benefits of cooperatives. (*Cooperative*, 2016)

In 2006, the No.1 document from Chinese government declared to strengthen the construction of new socialist countryside, and legalize and give strong support to the rural cooperative economic organization.

Hsieh Yingchun's team took construction cooperative into practice in Hebei, Beijing, Anhui, Xizang and many other places. The representative works include House Renovation in Lankao, Henan Province and Dongxincheng Village of Beijing. Before the farmhouse construction in Lankao village (Figure 199), Hsieh draws up a construction cooperative plan. He organizes the habitants to build their homes together. Construction Solidarity is based on labor exchange system developing from traditional mutual help among neighbors. The construction cooperative was established by local construction 'experts' for promoting green farmhouse and ensuring the efficient labor exchange and granting the villagers' committees more autonomy in construction activities. In addition, there are long-term low-interest loans and subsidies for green building construction.



Figure 199 cooperative housing in Lankao Village, Henan Province (Atlier-3, 2006a)

10.6 Ecological Demonstration House in Dingzhou, Hebei – Earth House 001 & 002

Zhaicheng Village is about 15km away from Dingzhou City, where the first Chinese rural cooperative – Yinli Cooperative was founded, is the birthplace of Chinese Rural Construction Movement, is known as the first democratic and autonomous village in China.

Currently, most villagers are middle-aged and elderly people lack education, and have little contact with the outside world. The village's economy and culture are in a self-sustaining cycle of growth. Most of the villagers earn their livings by farming, which restricts their incomes. The traffic is inconvenient, both in the village and the city.

Farmers build their rural residence autonomously in the village. The main participants of self-built housing are masons, carpenters, tenants, natives' relatives and friends. The houses usually use modern materials like brick, cement, steel, precast concrete. Most self-built houses are brick masonry construction, adopt one-floor slope roof prototype with life unit on the north and courtyard on the south. Usually, the labor amount for a brick masonry house is 6-7, while sometimes a dwelling can be finished by only one adult. With the economic consciousness of the villagers and the improvement of their living standards, current operation form has been more diversified, and there are cases built by the construction team. The land is the primary issue to be considered during construction. After the villagers get the land from the government, they can choose different ways to operate. There is hardly any design progress in self-built housing, because the house styles are imitated from the existing houses and the dimensions of the room and joint are based on experience. During the construction period, it is necessary for builders and occupants to carry out building within larger allowable error, more adjustable space and more

intuitive expectations, which means that open operation systems and low technology are very important. The participants in traditional rural housing are not paid, but are always treated to a few meals instead. On this occasion, the progress to build a house is not only a behavior of production but also a kind of social activity, which helps to form the consciousness of community on the basis of saving money. (Dou, 2016)

The construction of residential buildings usually cannot meet the requirement of the improving living standard. As a result, housing comfort is also a big problem, including indoor air quality, temperature, humidity, noise, indoor lighting quality, per-capita building area, etc. This is because usually only basic needs of the users are met due to economic reasons. So the problems of many physical performances of the buildings like noise insulation, lighting, heat and air quality and the performances of equipment and infrastructure are quite serious. In sum, the process of achieving safe, environmentally friendly, convenient, and comfortable dwellings needs to be accelerated.

On the other hand, a serious problem of culture deterioration arises with the rapid progress of urbanization, which shows that a lot of valuable traditions of architecture are vanishing as the local people are eager to integrate their architectural cultures into the prevailing city styles or “inherit” their architectural traditions very casually. Either from the environmental or cultural point of view, it is a destructive consumption of the cultural heritage resources. The rural residents pursue “new style” or “fashion” blindly but they do not have the chance to get the knowledge and can only superficially copy the “city style” in their minds. (Qu, 2009) Influenced by the trend of the times, rural residents use various pavements, doors, windows, roof tiles and ridge beasts to show off their personalities (Figure 200, Figure 201 and Figure 202).



Figure 200 Various doors of the farmhouses in Zhaicheng Village (Dou and Gong, 2014)

The quality of the house is mainly evaluated by the residents’ choice of cladding. Villagers who are relatively rich tend to create clean living environments with exterior wall tiles, cement floor leveling and an interior ceiling, while the low-income people maintain production and lives with

bare brick walls, rammed earth floor, and indoor wooden beams. (Dou, 2016) It means that the cladding is not only structure's shelter by material, but also the owners' taste and prestige.

For example, the style of door represents "face" (The term face idiomatically refers to one's own sense of dignity or prestige in social contexts in Chinese society) (Face (sociological concept), 2016). In order to show their prestige, people feel they have to keep up with the Joneses. So they built various archaistic doors, which "inherit" architectural traditions very casually.



Figure 201 Various eaves of farmhouses in Zhaicheng village (Dou and Gong, 2014)



Figure 202 Various finishes of farmhouses in Zhaicheng Village, printed ceramic tile finish (left), ordinary ceramic tile finish (window), mortar finish (right) (Dou and Gong, 2014)

The various eaves and finishes also represent "face". The printed ceramic tile finish represent the highest dignity, because it is the most expensive finish in the village. Mortar finish is the cheapest and functional way, but means "loss of face" for them. The three kinds of finishes show in Figure 202, from left to right, the "face" is from more to less.

The villagers' attitude towards the covering layer demonstrates that they care about architectural appearance rather than housing comfort. For example, the thermal performance of cladding always is ignored. The rural residents even value their faces much more than urban residences. (Dou, 2016)

Hsieh sees the kind of rural construction as the monopoly and high costs of construction businesses, whose materials and designs usually have little to do with local environmental conditions or local communal traditions. The architect sees much of the homebuilding industry as exclusionist, fostering "closed" practices that have held homeowners captive for decades, locking them into life-long mortgage payments in the process. (Stanley, 2009)

Hsieh Ying-chun introduced his open construction system to mainland China, cooperated with James Yen Village Rural Construction Institute, constructing urine-diverting dry toilet and demonstration green farmhouses. In spring 2005, he set up ecological building course in James Yen Village Rural Construction Institute (JYVRCI) in Zhaicheng Village of Dingzhou, Hebei Province. From 2004 to 2006, cooperating with JYVRCI, Hsieh Ying-chun organized college student volunteers to build demonstration rural houses - Earth House 001 and Earth House 002 in the campus of JYVRCI, in order to research ecological housing and propagandize Construction Solidary. Inter-subjectivity is encouraged by Hsieh Ying-chun to deal with the relationship between the designers and occupants. After the architects set up an opening platform, the building workers and dwellers can participate in the construction progress, put forward design concepts from different perspectives and embody living conditions, cultural environment and religious beliefs through the residential. (Dou, 2016)

Earth House 001

The Earth House 001 is the first prototype house that he designed for northern rural areas of China.

The timber frame of earth house 001 is based on traditional Chuandou timber frame, diagonal bracing was added to provide stability and resists lateral loads. All the wood materials used for Earth House 001 are recycled from demolition waste or harvested from the artificial forest. Farmers in the village have a tradition of planting trees for building materials nearly ten years before construction. So harvesting trees for rural residences don't conflict with the forest conservation. And they use straw, reeds earth, stone, bamboo, timber, brick, straw, cloth, plant-weaving material, metal, etc. for infills. The process of production and manufacture of the building materials (timber, earth, straw, bamboo, straw mat and a series of reed products, such as reed mat, reed foil, reed board, etc.) can reduce carbon dioxide (CO₂) emissions. In addition, use of non-recyclable materials like brick, concrete is minimized. (Qu, 2009)

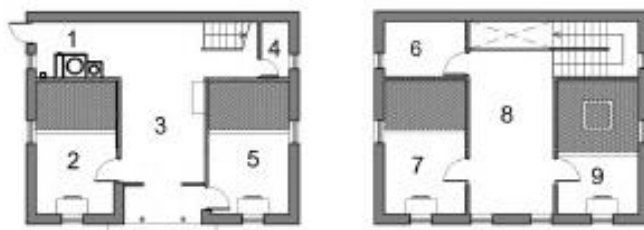


Figure 203 First and second-floor plan of Earth House 001

1. Kitchen 2. Bedroom 3. Living-room 4. Toilet 5. Bedroom 6. Storage 7. Bedroom 8. Living room 9. Bedroom (Atlier-3, 2011a)

Other than the traditional one-story, five-axis and one room-depth dwelling in Zhaicheng, earth house 001 was designed two-story and three-axis. A half more room-depth was also added to the plan of earth house 001 as the space for kitchen, bathroom, staircase and lighting patio, which do

not exist in the local houses (Qu, 2009) The front flat roof is for drying grains.



Figure 204 Façade 1 (left), Façade 2 (middle), Section (right) (Atlier-3, 2011a)

To strengthen the earth wall, the bottom of the exterior wall was covered by wire netting and bricks to protect the wall from rain-wash and the invasion of mice. The heating in winter is the local traditional way – heatable brick bed. But the construction was improved to a double-level energy-saving one to adapt for the two-story house.



Figure 205 (left) Exterior of Earth House 001 (Atlier-3, 2010)



Figure 206 (right) Interior of Earth House 001 (Atlier-3, 2010)



Figure 207 (left) timber framing (Roan, 2007)



Figure 208 (right) College student volunteers and Villagers built Earth House 001 together (Roan, 2007)

Earth House 002

Hsieh Ying-chun built Earth House 002 after Earth House 001. The construction is light steel

framing with straw-clay infills. (Figure 209)



Figure 209 Earth House 002 structure is light steel frame and straw-clay wall (Atlier-3, 2006b)



Figure 210 First and Second-floor plan of earth house 002 (Atlier-3, 2011b)

1. Living room 2. Dining-room 3. Kitchen 4. Sunroom 5. Stairway 6. Living room
7. Bedroom 8. Bedroom 9. Balcony

Earth House 002 adopt the same prototype with Earth House 001, two floors and three rooms. A single-flight stairs in the north of the house links two floors.



Figure 211 Façade 1 (left), Facades 2 (middle), Section (right) (Atlier-3, 2011b)

The connection between steel members are made of bolts, which “enables the non-professionals can manipulate easily all the operation procedures” (Qu, 2009)

As prototype houses, the cost of earth house 001 and 002 is each 50, 000 RMB. In addition, if the farmers build by their own, they don’t need to buy straw and earth like Hsieh Ying-Chun, and they can ask friends and relatives to help and also save the cost of labor. Thus the cost can be controlled under 20, 000 to 30, 000 RMB, which is quite low in China. (Qu, 2009)



Figure 212 Construction process of Earth House 002 (Atlier-3, 2006b) (Shi, 2011)



Figure 213 walls and bamboo floor leveling being built, Earth House 002 (Shi, 2011)

The walls use bamboo, straw and earth. The second floor leveling uses bamboo. (Figure 213)

Modular system of Earth House 001 and Earth House 002

In traditional Chinese building culture, the concept of 'Jian' forms the order of the space. The modular dimensions of 'Jian' in Earth House 001 and Earth House 002 are 3.3 m or 3.6m. Based on the thin-walled light steel structure and considering regional characteristics, length limit of raw materials, user acceptance, land area, construction cost and other factors, the column spacing of the frames are 1.1m, 1.2m, 1.22m. Housebuilders can divide the interior space and change the functions of the room according to their needs, and the flexible adjunctions added by the users reflect the architectural diversity of rural housing. The modular system indicates the elasticity of Construction Solidarity. (Dou, 2016)

10.7 Conclusions

Construction Solidarity promoted by Hsieh Ying-chun has feasibilities in rural China. In many areas of rural China, people maintain the traditional mutual assistance construction. And most people have freedom to build. They have self-building experience and desire of taking part in design and construction of their own dwellings.

Construction Solidarity converts traditional self-built rural housing to labor-exchange system. Inter-subjectivity balances the relationship between the designers and occupants.

Construction Solidarity has advantages. Firstly, it has a price advantage because of labor-exchange system.

Secondly, the designers and occupants work together to optimize the housing design. Occupants' social, cultural and aesthetic requirements are taken into the consideration by designers' site, structural, space and detail analysis, in this way vernacular building culture integrates with the open construction system to reach various housing prototypes. On the other hand, designers introduced modern flexible space division and functions into rural houses, and guarantee house quality and speed up construction. Therefore, the prototypes can be optimized through designers' intervention and residents' participation emphasized by construction solidarity.

However, construction solidarity also has shortcomings. Firstly, the designers as the organizer and intervenor in the rural construction, always don't have enough understanding of rural life and accumulation of prototypes. Thus, the new techniques introduced by them may be not accepted by the occupants. For example, in the post-earthquake reconstruction project in Yangliu village organized by Hsieh Ying-chun, after the architects and volunteers left, the local villagers didn't use the building techniques learning from the demonstration projects anymore. The technology transfer failed. The reasons are: 1) the steel members can't be manufactured in the village due to the low level of industrialization. The steel members were transported from outside. Long-distance transport and wastage in the transit increase the cost. 2) Hsieh's LGS framing have to be

calculated and designed by engineers. The villagers can't construct it without engineers. 3) Because the strict and complicate assembling order of Hsieh's LGS framing made the builders more prone to error, the works had to be redone frequently which increased the cost. 4) The villagers would like to build with timber and stone rather than light steel because they have confidence in their own building culture. The designers didn't get sufficient support of grassroots.

Secondly, construction solidarity requires more organization work because training and education are essential.

The open construction system makes possible the participation of occupants. Hsieh's team developed a new light gauge steel (LGS) framing based on the LGS framing and traditional Chuandou timber framing. The construction operation of Hsieh Ying-chun's LGS framing is similar to the traditional Chuandou frame method, which is understandable for the villagers in the southern mountain area. Hsieh Ying-chun's LGS framing combined industrial production and low-technology, and simplified connection. The non-professionals can grasp the building techniques quickly. It is also energy-saving, light-weight, anti-seismic, extendible, simple to operate and allows a variety of infills, but has technical difficulties in interior decoration, sound-proof and heat preservation.

After more than ten years of practice and research, construction solidarity and open construction system are highly developed. Nevertheless, there are still many subjects to discuss. Firstly, it is difficult to balance between the old and new building cultures, and the relationship between designers and occupants. Skillful communication and cooperation are essential. Secondly, high-quality design and construction standards during the simplification of technology have to be ensured. Thirdly, it is important to ensure efficient organization work, supervision, education and training for non-professionals to avoid error in the construction. Fourthly, long-term funding, grassroots' support and political commitment are essential for technology transfer. Finally, the development of Hsieh's LGS framing needs a relatively high level of initialization. And Construction Solidarity development needs an open social culture, because it is based on the acceptance of outside intervention.

11 Structural art of traditional reciprocal frame

Reciprocal frame could be heavy-frame construction (heavy framing) if the pieces are few and heavy or many and smaller called light-frame construction (light framing). Reciprocal frame can achieve long span and a wide variety of architectural styles. The structural members are connected with hinge joints which allow for vertical and horizontal rotations.

Reciprocal frame could be heavy-frame construction if the structural members are few and heavy such as in timber framing or light-frame construction using many and smaller standardized dimensional lumber.

11.1 Reciprocal frame bridge and ancient painting 'Along the River During the Qingming Festival'

The Rainbow Bridge in the famous painting *Along the River During the Qingming Festival* was built (Figure 214) in Northern Song period (960–1127). It is heavy reciprocal framing. Such bridge began to be popular from Song Dynasty.



Figure 214 The Rainbow Bridge Scene, *Along the River During the Qingming Festival* (Guan, 2016)

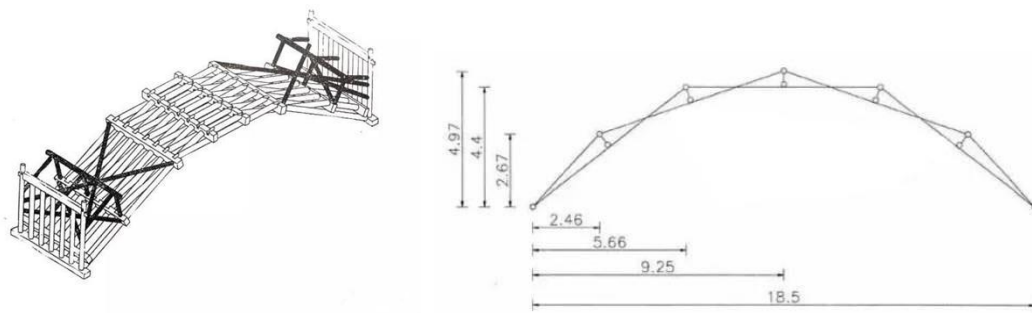


Figure 215 (left) Reciprocal Frame of Rainbow Bridge (Guan, 2016)

Figure 216 (right) Structural Analysis of Rainbow Bridge (Guan, 2016)

Reciprocal frame bridges have high compressive strength, but can't resist earthquake. So they distribute in Fujian and Zhejiang where have never had an earthquake. There are more than 100 reciprocal framing Covered Corridor Bridges remain today in China. For example, Luanfeng Bridge from Ming Dynasty (1368—1644) still stands today in Fujian, as shown in Figure 217, Figure 218 and Figure 219.



Figure 217 (left) Luanfeng Bridge, Fujian, China (Fujian Tourism, 2016)

Figure 218 (right) Luanfeng Bridge, Fujian, China (Fujian Tourism, 2016)

Length: 47.6m Width: 4.9m Net span: 37.2m



Figure 219 (left) Luanfeng Bridge, Fujian, China (Guan, 2016)

Figure 220 (right) Structural Analysis of Covered Bridge (Source:

<http://travel.sohu.com/20160311/n440147373.shtml>)

Newly Built Traditional Covered Bridge

The construction techniques of covered bridge remain in Zhejiang and Fujian. There are newly built covered bridges in some rural areas, as shown in Figure 221 and Figure 222.



Figure 221 (left) A Covered Bridge (Source: <http://www.jeed.com/read/1835641106/>)

Figure 222 (right) A Covered Bridge, Taishun County, Zhejiang Province (Source: <http://www.jeed.com/read/87067321/>)

11.2 Reciprocal frame roof

Reciprocal frame roof is inspired by the traditional reciprocal frame bridge. It is widely applied in the contemporary natural building. It is a type of heavy frame roof in which three or more beams provide mutual support, avoiding the need for the main beam that crosses the house, or a central post. The structural material can be timber or bamboo.

It's a self-supporting structure, in which each beam rests on the previous one, and the last beam fits underneath the first one. While building it you need to support the first beam temporarily; when the support is removed the whole structure should neatly lock together.

Reciprocal frame roofs are beautiful and strong but rather fiddly to build — especially when it comes to cladding the roof structure with boards. (*Reciprocal roof*, no date)



Figure 223 (left) Reciprocal frame roof, Mas Franch, Olot (Author's own photographs)

Figure 224 (right) Skylight of the Reciprocal frame roof, Mas Franch, Olot (Author's own photographs)

The beams and columns are connected with hinge joints which allow for vertical and horizontal rotations.

11.3 Wa Shan Guesthouse



Figure 225 (left) the 120-meter long roof of Wa Shan Guesthouse, Xiangshan, China (Guan, 2016)

Figure 226 (right) the 120-meter long roof of Wa Shan Guesthouse, Xiangshan, China (Source: <http://www.kaoder.com/?m=thread&a=view&fid=64&tid=179410>)

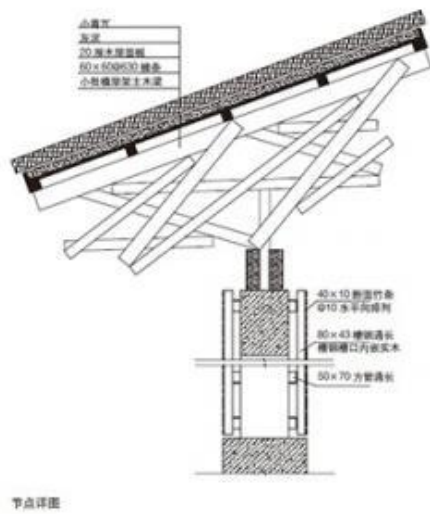


Figure 227 Section of reciprocal frame roof (Source: <http://www.kaoder.com/?m=thread&a=view&fid=64&tid=179410>)

The guesthouse has a 120-meter continuous long roof. It is light reciprocal frame using many small pine wood bars. The joints of the bars are hinges.

11.4 Installation artworks of Amateur Architecture Studio: Decay of a Dome



Figure 228 the 'Decay of a Dome' installation by Wang Shu, Vito Bertin, and Lu Wen Yu

of Amateur Architecture Studio (Lu, 2012)

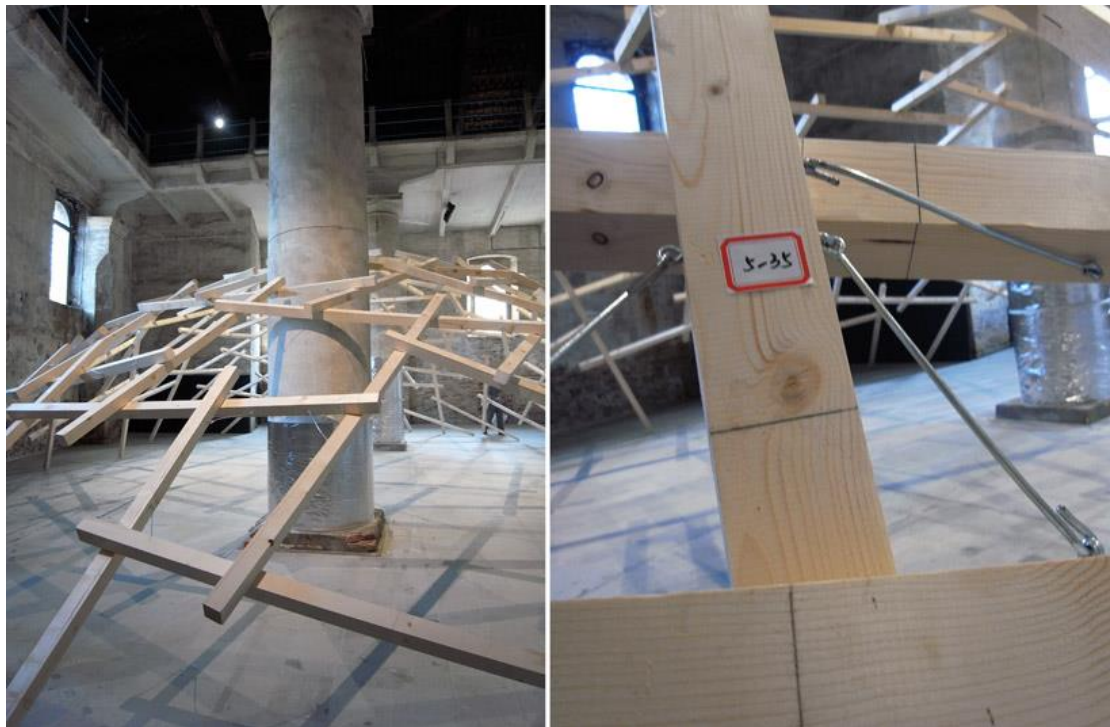


Figure 229 Decay of a Dome (Helene, 2010)

The 'Decay of a Dome' installation by Wang Shu, Vito Bertin, and Lu Wen Yu of Amateur Architecture Studio from China is a very light structure, with a shape similar to the dome of western buildings, but its construction principle is also like those of traditional Chinese buildings. It does not need a base, so the construction does not damage the ground. It contains the least components and the simplest construction principles. It is traditional reciprocal frame structure. The wood pieces are connected with cabin hook. It can be both quickly constructed and dismantled. Therefore it is also easy to move. Though the construction will need many hands – a group of people to assemble – even those who know little about architecture can participate. The rational construction becomes a nastic construction. (Helene, 2010)

Rather than looking only towards the west for inspiration as many of their contemporaries do, the practice's work is embedded in the history and traditions of Chinese culture. In particular, they reference everyday building tactics of ordinary people and the strong vernacular tradition of building in China.

The name of their practice signals this commitment to learning from the 'amateur builder', focusing on craft skills and applying this to contemporary architecture.

11.5 Installation artworks of Amateur Architecture Studio: 'Squarely Sphering' Structure



Figure 230 'Squarely Sphering' is a full-scale pavilion prototype by Wang Shu of Chinese practice amateur architecture studio (Designboom, 2012)

'Squarely Sphering' is a full-scale pavilion prototype by Pritzker prize winner Wang Shu of Chinese practice amateur architecture studio, on display within the upper plaza in the Shenzhen Civic Center, in China during the 2011 Shenzhen & Hong Kong Bi-City Biennale Of Urbanism \ Architecture.

Resting upon the pavement without foundations, the small building is conceived without any anchor to the ground and is constructed with the lightest materials possible. The wood pieces are connected with cabin hook. It can be both quickly constructed and dismantled. Therefore it is also easy to move. Though the construction will need many hands – a group of people to assemble – even those who know little about architecture can participate. Addressing sustainability and the age-old question posed by Buckminster Fuller to architects: 'how much does your building weigh', an efficient framework of short lumber components creates a tubular form, protected with translucent polycarbonate sheets. This is one element within the 'Ultra-Light Village', an open air exhibition curated by Terence Riley provoking questions of the nature of permanent versus transitory construction in the creation of cities. (Designboom, 2012)



Figure 231 Entry to 'squarely sphering' structure (Designboom, 2012)



Figure 232 Bench seating lines the length of the tubular structure (Designboom, 2012)

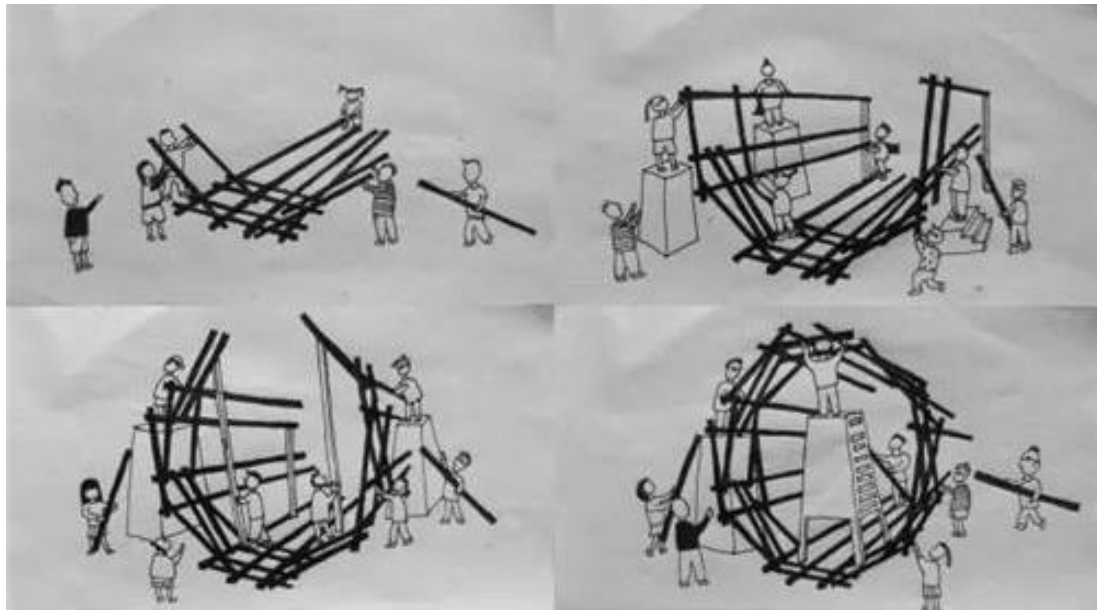


Figure 233 Building process (Guan, 2016)

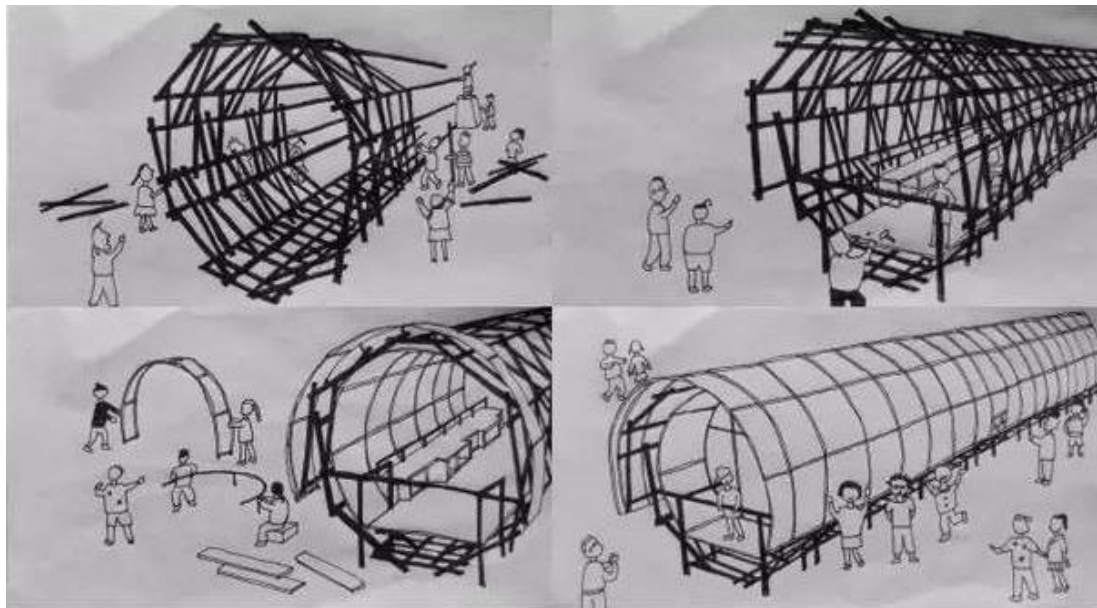


Figure 234 Building process (Guan, 2016)

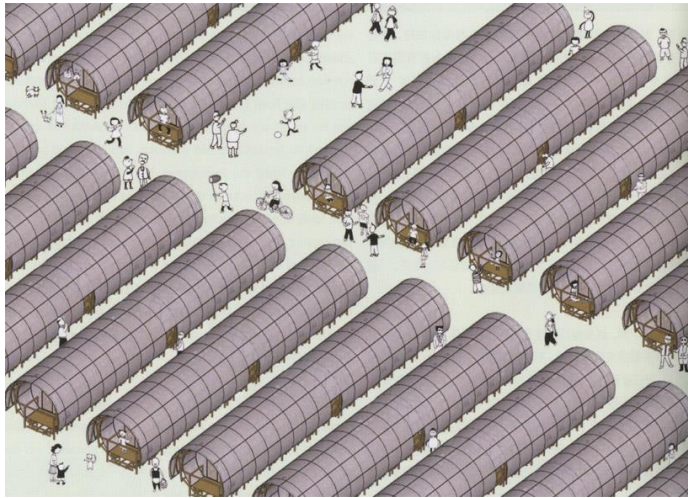


Figure 235 Rendering of complete village (Designboom, 2012)

The 'Squarely Sphering' structure can be a post-disaster temporary shelter for rural areas, as shown in Figure 235.



Figure 236 (left) Dismantling 'Squarely Sphering' structure (Bi-City Biennale, 2014)



Figure 237 (right) Pieces of 'Squarely Sphering' structure (Bi-City Biennale, 2014)

'Squarely Sphering' structure was moved to various places of Shenzhen during the Bi-City Biennale of Urbanism/Architecture 2011. Every time when it was constructed, dismantled and moved, it interacted with different people and played a new role in the new surroundings.

11.6 Conclusions

In Chinese traditional building culture, reciprocal frame is usually applied to timber bridge. The construction has high compressive strength, but can't resist earthquake. The joint of reciprocal frame is hinge which allows for vertical and horizontal rotations. It can be both quickly constructed and dismantled. Therefore it is also easy to be recycled. The construction technique is simple, so people who know little about architecture can participate.

Contemporarily, reciprocal frame is developed into various structure shapes which can be divided into two broad categories, heavy-frame construction and light-frame construction. Chinese traditional timber covered bridge and reciprocal frame roof are heavy-frame construction. The installation artworks, 'Decay of a Dome' and 'Squarely Sphering' and the long roof of Wa shan Guesthouse designed by Wang Shu are light-frame construction.

The structural pieces of heavy-frame construction are few and heavy, can be timber or bamboo after simple manual processing. So heavy-frame construction can adapt to areas with low-level industrialization. In some rural areas in China, people still build traditional timber covered bridges. In Europe, reciprocal frame roof is applied to natural building.

The structural pieces of light-frame construction are many and smaller. Light-frame construction using standardized dimensional lumber has become the dominant construction in some industrialized countries because of its economy. Wang Shu designed reciprocal frames using standardized dimensional lumber. Such construction can achieve a long span, a wide variety of structure shapes and architectural styles. It has advantages of both light frame and reciprocal frame. It is simple, light, reusable, temporary, suitable for DIY (Do It Yourself), easy to move, and can be both quickly constructed and dismantled. When moving to a new place, it can adapt to new surroundings and take effect right away. This type of construction inherits the philosophy of Chinese vernacular architecture - pragmatism.

12 General Conclusions

As we said before, because of the serious culture deterioration in rural China, the rich and colorful vernacular architecture is replaced by the same awful brick masonry buildings confined with concrete beams and columns. Because of a lack of professional support and building code, the self-building housing projects are unsafe and uncomfortable, and the orientation of the houses and the layout of the clusters are in disorder so that waste of land is serious. Furthermore, the rural residents also suffered from the poor infrastructure construction. Many large-scale rural reconstruction projects are failed because of corruption and irresponsibility.

By researching the installation artworks, rural reconstruction projects and traditional rural settlements in China, I attempt to point out the ills and propose the resolutions, which can be interpreted from the aspects of art, sociology, politics, economy, construction management and technology, and philosophy.

From the aspects of art and aesthetic, the appreciation of beauty in many rural areas is lost along with the disappearing of the traditional craftsmen and rural intellectuals. In many villages, the appearances and architectural plans are quite different from one another and not compatible as well. And the rural residents pursue “new style” or “fashion” blindly but they do not have the chance to get the knowledge and can only superficially copy the “city style” in their minds. Influenced by the iconic architecture in the cities, they also “inherit” cultural elements of their vernacular building culture very casually. Rural housing is mixing architectural styles which have icons from the vernacular, modern architecture or even exotic style. From the cultural and aesthetic point of view, it can be argued that it is a destructive consumption of the cultural heritage resources. But it also can be argued that the vernacular and modern architecture have been removed and conquered by the free, open, pluralistic architectural styles to form an iconic landmark and to produce an exhibition of contemporary style architecture. The barefoot architect Xu Yixing attempts to bring back the original beauty of Liangshan Yi people’s vernacular architecture. His project - Liangshan Children’s Hope Home uses the traditional construction techniques, timber structure and decoration. However, his work is hard to go forward. Because the traditional craftsman is rare and the traditional building process is inefficient and labor-intensive which doesn’t conform to the industrial age. The American architect, Kelly Lerner, takes a different approach, to achieve her ultimate goal of technology transfer, she designed the houses which are culturally and aesthetically pleasing. In my opinion, the architects shouldn’t confine vernacular architecture to a particular style, but tried to find a compromise balance when homeowners’ aesthetic preferences occasionally conflicted with the principles of pleasure in design.

From the aspect of politics, sociology and economy, the renovation of vernacular architecture needs political commitment, support of local community and long-term funding. Currently, the

government becomes more conscious of rural construction. However, the government has implemented a lot of exploitative housing projects in rural areas. These homes become a financial burden for rural residents. The foundations, activists, architects and NGOs also have intervened in the rural reconstruction. These groups and individuals cooperated with the government and rural residents. The rural residents are the main decision-makers in the multilateral cooperation, which reduces corruption and oppressive political hegemony. To resolve the economic issues, the rural residences require a viable alternative in the form of a semi-independent construction system, housing cooperatives, and a micro-finance supporting strategy. That is a big challenge for NGOs and activist-architects. The behavior of mobilizing neighbors to participate in construction in an agricultural society, evolved into construction cooperatives based on labor-exchange system in industrial society, especially in rural areas. However, in many remote villages in mainland China, construction cooperatives have not been formed. The NGOs and architects could cooperate with the local construction experts to establish construction cooperatives for ensuring the efficient labor exchange and granting the villagers' committees more autonomy in construction activities. The financing mode can be government granted, foundation granted, farmers' self-raised funding, and government-guaranteed loan.

From the aspect of construction technology, in many rural areas, people like to build brick masonry houses confined with concrete beams and columns. The vernacular architecture using various natural materials is not welcome, because there is no corresponding building code and industry of building materials and tools, and people look upon natural building materials as a symbol of poverty. Indeed, the low-cost and labor-intensive construction can adapt to the low level of rural industrialization in the most remote poor villages in China. However, for long-term development and technology transfer, we should develop corresponding building codes and industry. The architect Hao Lin developed the reconstituted bamboo industry and used the Canadian wood building codes for reference in his bamboo building projects. The architect Liu Jiakun promoted the industry of 'Rebirth Brick' and proposed the corresponding construction technology. The development of sustainable natural building can be the driver of innovation and industrialization in rural China. Natural buildings take full use of local resources and can be labor-intensive and economical to kick off the pilot projects. When there are enough examples well tested and monitored and the demand for natural building materials exceeds the supply, building codes will be established, and technology transfer, mass production, and emerging related industries will follow. The industrialization will drive the creation of businesses and markets, speed up the development of rural economy and transfer of rural labor force.

From the aspect of construction management, the main issue is to deal with the relationship between architects and homeowners. For many architects, working in a rural environment is a new experience. The myriad diverse tasks were far beyond their experience, and the solutions provided by them were thus, very often, inappropriate. While local people are rural experts, they have developed appropriate habitat designs and technologies over centuries. So, architects, planners, and engineers shouldn't be assigned responsibilities unquestioningly during the

project. They can act enabling the provision of professional knowledge. The relationship between the architects and residents in the construction cooperatives can be: the architects simplify the construction procedures, provide an open construction system and deal with technical issues, while the residents reflect living conditions, cultural environment, and religious beliefs. The open construction system enables Do It Yourself (DIY), because of its simple and cheap construction technology. Under this mechanism, a semi-autonomous construction system responding to cultural diversity is formed and residents' community awareness is established during the construction process, which may be a possible solution to Chinese rural housing problems.

From the aspects of philosophy, Chinese vernacular architecture focus on pragmatism over idealism. Specifically, Chinese vernacular architecture is usually simple, light, reusable, removable, temporary, suitable for DIY, easy to move – that's to say, sustainable – and can be both quickly constructed and dismantled; when moving to a new place, it can adapt to new surroundings and take effect right away. On the other hand, Chinese vernacular architecture is implicative and discreetly integrated into its environment. It usually doesn't have an amazing appearance, but has artful space connections inside.

13 Annex

13.1 Mas Franch

DATE: 08/02/2016 – 21/02/2016

PROJECT NAME: Mas Franch

LOCATION: St. Feliu Pallerols (Girona)

SIZE: 2 ha

DATE DESIGNED/PLANNED: 2007

DESIGNER: Mas Franch Collective

CLIENT/DEVELOPER: Mas Franch

MANAGED BY: managed by the collective. Richard Wade as tutor

Web Site: www.masfranch.org

There are farm, hostel, restaurant, kitchen, storage, henhouse, dry toilet, swimming pool, Youth Free time place and residence in the place.

I participated in the construction for two weeks and interview with Irene, the stable member of the community.



Figure 238 rural house (Author's own photographs)

The rural house was built in 12th century. The members of Mas Franch community renovated and extended it. And they installed a solar electrical energy generation system for the rural house.

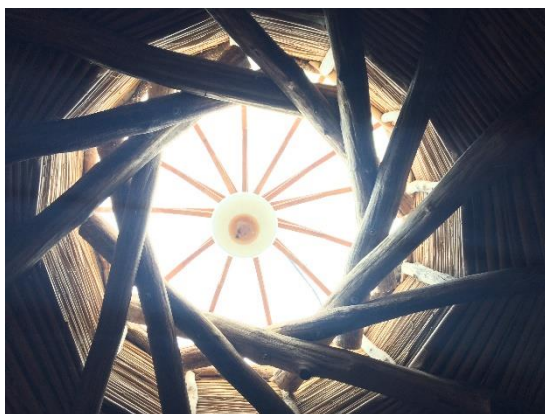
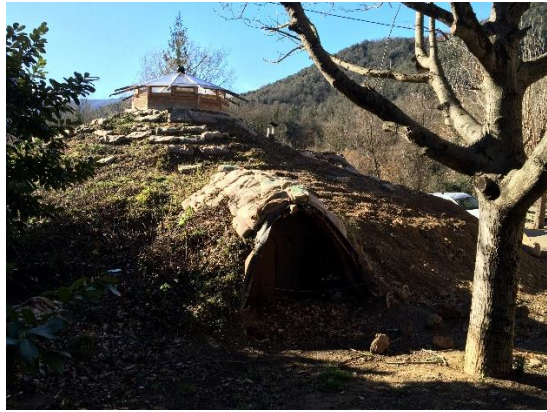




Figure 239 Round House (Author's own photographs)

The round house uses natural materials: wood, bamboo, straw and earth. It is timber structure, the roof is reciprocal frame. The walls use rammed earth and straw bale. It is a green roof. There are seeds in the earth bag on the roof. There is a rocket stove inside. A rocket stove is an efficient and hot burning stove using small diameter wood fuel. The round house is for activities like yoga, meditation, dance, etc.



Figure 240 composting toilet (Author's own photographs)

The composting toilet uses a predominantly aerobic processing system to treat human excreta. The toilet use no water and can be used as an alternative to flush toilets.



Figure 241 farm and henhouse (Author's own photographs)



Figure 242 Natural Swimming Pool (Author's own photographs)

A natural swimming pool utilizes reed bed technology to filter out dirt from the water naturally. Free from chlorine and other harmful chemicals. They have used large areas of bed with a simple pump to circulate. The cold circulating water is from the stream where the water is cold and the water is constantly being refreshed.



Figure 243 kitchen and barbecues (Author's own photographs)
The decorations on the wall and the chair is made of straw and clay.

The interview with Irene, the stable member of Mas Franch Community

What's the use of the place?

The place is used for Private Youth Hostel, Permaculture Center, and Open Centre for Courses like yoga etc. The rural house offer 70 beds for visitors. The round house is for activities like Yoga, meditation, dance, etc. And we have a basketball court for fun, which is a great addition for facilitating teaching and training. We have a lot of permaculture elements for teaching and training: garden, greywater system, ecological building, and social networking.

Does your community offer opportunities for volunteers or study tours?

Yes, we welcome visitors. We offer accommodation. Mas Franch is a host in WWOOF. And people also can write us emails directly. Volunteers participate in the construction and farm work. We hope that the volunteers can stay for more than a week. We want more local people, because they are more flexible. We also can receive big groups.

How did you start your community?

The project is started 2007. Initially, we are a community of 7 people, then people go and come, now we are 5 people. We are a very open community. We hope it to form more diversity of people. The owner rented the rural house to us. And we tried to redesign and rebuild the house. And we attempt to change the place more sustainable.

Do you cooperated with other organizations? How do you resolve financial problem?

Yes, we worked with different NGOs, for example Peace Brigades International and different local social movements. Our first Permaculture Design Course was organized by Spanish Permaculture Institute. After, we organized one Permaculture Design Course per year, organized by Montsant Institute of Permaculture.

We are supported by long-term funding from foundations.

How do you design, develop and construct your projects?

We have two groups in design and construction. One is the group of 5 stable members who make decisions of the projects. Another group is a temporary community of volunteers – people wanting to study natural building and ecological life who participate in the design and construction.

The design of the community is a collective work. The 5 stable members are in charge of different parts. In the most important period for the design, for example, the structure design, water system, we have technological supporter, Richard Wade.

What is the project significance and impact?

We change a normal farm with Permaculture ideas. And we interact with many people

worldwide.

What's the limitation of the Mas Franch?

We can't build more houses because the natural park is around the place, the space is too small. So our stable members can't exceed 12 people. And money and people for developing the community are changing often.

Where do you collect these natural building materials?

We harvest wood and bamboo in the mountain. The straw is recycled from the farms nearby. We buy stones, sand and wood floor. The earth for construction is recycled from the building waste of the construction nearby.

How about your community members?

Our stable members are people from cities who wanted to change their life. We are interested in permaculture and wanting to experiment. We welcome volunteers who want to try a community life. People who want to become stable members have to stay here for more one year.

What do you learn from the project?

Initially, there was only the rural house. We didn't know how to design an ecological construction. We had to restudy all the knowledges. And we didn't have all the important information about climate, water, geography and limitations of the place. The lesson learned from it is that we should get more information before we started.

Do you have future plans?

Yes, our work will more focus on Permaculture. We will organize more activities for people interested in Permaculture. And we will organize specific activities to introduce Permaculture to people who are not so much interested in it. We want to set up a Permaculture College, which is accessible to everybody and cheap.

13.2 Meditation Home

Working with Santiago Cirugeda



Figure 244 Meditation Home in Vipassana Meditation Center, Santa Maria de Palautordera, Barcelona (Author's own photographs)

Date: 13-14 January 2016

I participated in the construction of the Meditation Home.

The Meditation Home is built on the swimming pool in the courtyard of Vipassana Meditation Center Santa Maria de Palautordera, Barcelona. The construction materials of the frame and the walls are H wood beam, Oriented Strand Board (OSB). The exterior walls are decorated with firewood. The construction was organized by Santiago Cirugeda, the construction system is open to all people, volunteers are unprofessional local people, tourists and his fans. The tools are simple to use. There are a staple gun, some electric drills and saw. The wood columns are fixed on the concrete with bolts.

13.3 La Escuela Crece

Working with Santiago Cirugeda





Figure 245 La Escuela Crece, la Escuela Superior de Diseño de Madrid (Author's own photographs)

Date: 15-17 December 2015

Project: Eighteenth workshop of Growing School (La Escuela Crece).

I participated in the construction of Growing School.

The Growing School is located in the Escuela Superior de Diseño de Madrid. It will be used for classroom and exhibition hall. It is a self-building project organized by Santiago Cirugeda. The workshops are open to all people. The volunteers participated in the projects work with electric drills and saws. The container, the windows and doors are recycled. The removable steel construction is the product of RH Estructuras Company. Some doors and windows are designed by the volunteers in the construction process.

13.4 Shell Greenhouse, El Palmar, Valencia

I participated in the project when working in Canyaviva Association.



Figure 246 Location and effect drawing of the Shell Greenhouse (work and illustrations of author and her colleagues)

Date: 1 May – 31 Aug 2016

Project: Shell Greenhouse

Shell Greenhouse is located in a private wharf by the Albufera, El Palmar, Valencia.

The client is the owner of the wharf.

The staffs of Canyaviva Association designed and built the Greenhouse.

The giant cane (Arundo Donax) is harvested in field nearby Barcelona. We transported them to the workplace in Mataró and made them arches and ribs. Then we transported them to the wharf in Valencia and assembled them on site. The canes and the angle steels are connected with hemp rope.

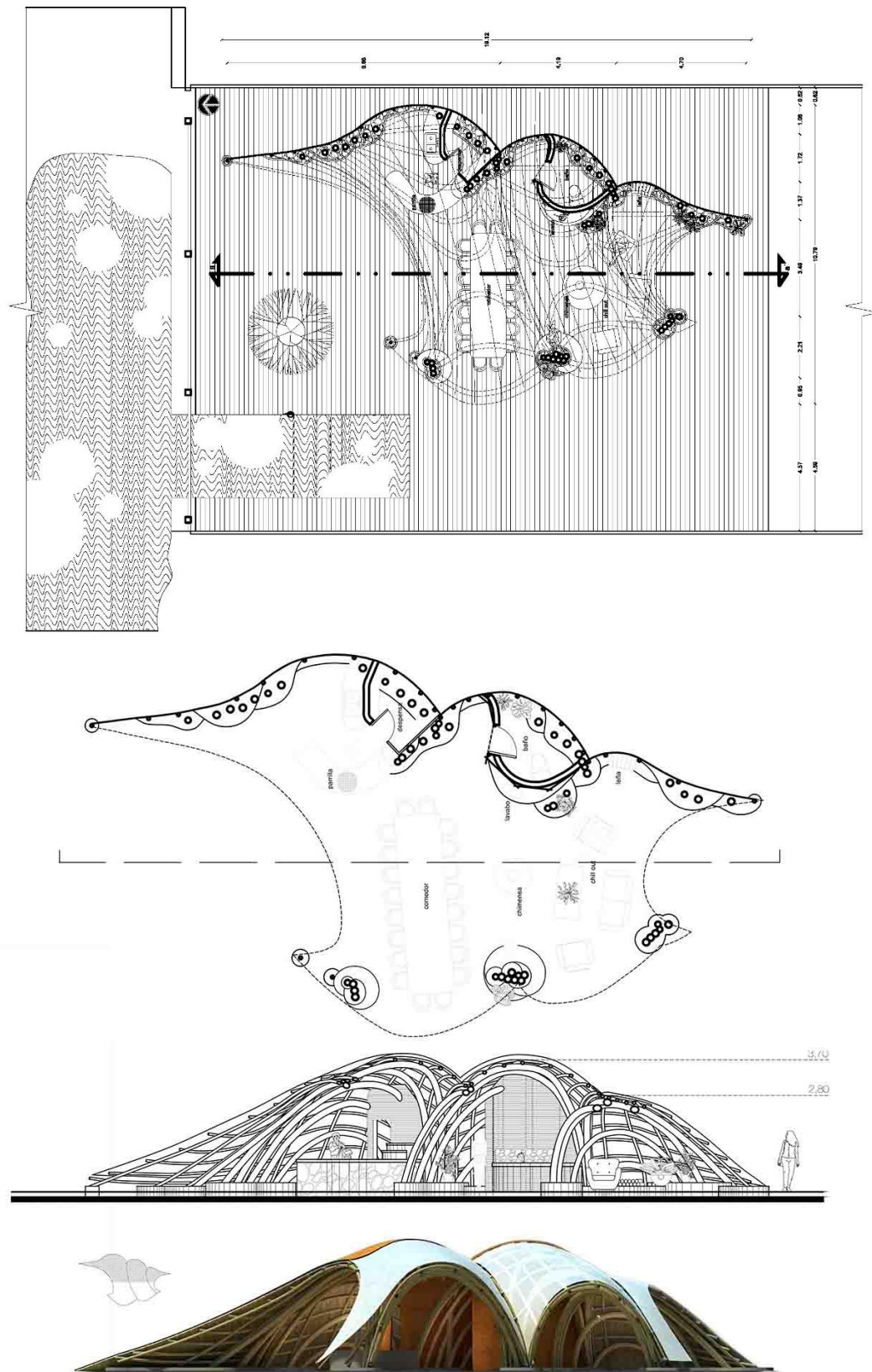
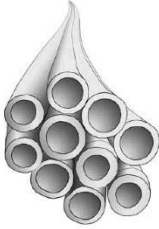


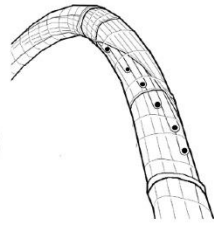
Figure 247 Plan, section and façade of the Shell Greenhouse (work and illustrations of author and her colleagues)

BUILDING WITH ARUNDO DONAX

MAKING CANE



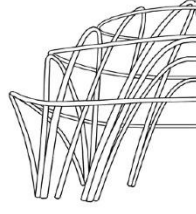
ARCH



PRINCIPAL STRUCTURE



SECONDARY STRUCTURE



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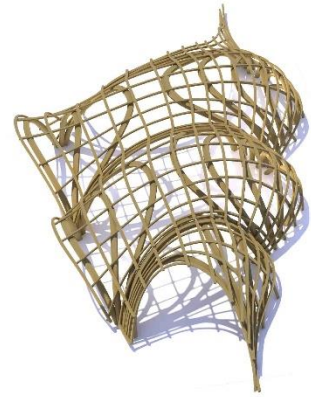
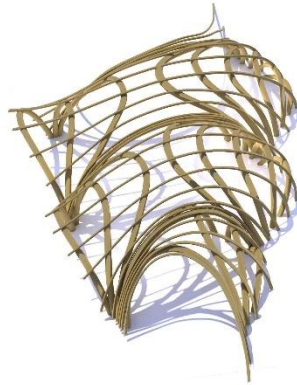
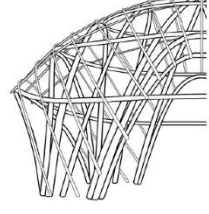




Figure 248 the construction process of the Shell Greenhouse (work and illustrations of author and her colleagues)

13.5 Porch and storage in Riera de Can Soler, Mataró

I participated in the projects when working in Canyaviva Association.



Figure 249 Porch, Riera de Can Soler, Mataró (Author's own photographs)

Date: Apr 2016

The arches and ribs are made of Arundo Donax cane, and are covered by lime.



Figure 250 Storage, Riera de Can Soler, Mataró (Author's own photographs)

Date: Apr 2016

The storage is for protecting the Arundo Donax cane.

The arches and ribs are made of Arundo Donax cane.

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